Acoustic Survey Cruise Report

ICES Divisions VIIb,j & g and VIIaS

Photo: Dave Wall

CELTIC SEA HERRING ACOUSTIC SURVEY

RV CELTIC EXPLORER

1st – 21st October 2006

Reported by

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Fisheries Science Services, Marine Institute, October 2006

Introduction

In the Celtic Sea and ICES Division VIIj the herring fishery is divided into 3 main catching seasons. In quarters four and one, the fishery is focused on autumn and winter pre-spawning and spawning aggregations. In the 2004/05 season 34 vessels participated in the fishery, ranging from small dry hold polyvalent vessels (<20m) to purpose built RSW (Refrigerated seawater) vessels of 23-40m. Single and pair midwater trawling are common, with the latter representing the preferred catching method. In recent years a quarter-3 summer fishery has developed targeting offshore feeding aggregations, 78nmi (nautical miles) offshore on the Labadie Bank. This offshore fishery is restricted to the RSW fleet on the grounds of product quality delivered to processors.

For the 2005/06 season the TAC available to Irish vessels was 9,549t (ICES Divisions VIIg,h,j and k and VIIaS combined) and was taken relatively evenly across the three catching seasons. This is a reduction of 15% on the 2004/05 season, when the TAC was 11,236t.

The coastal fishery in VIIj traditionally runs from early October until January and is concentrated within several miles of the shore including many bays and inlets. The VIIaS fishery peaks towards the year end in December, but may be active from mid October depending on location. In VIIg, along the south coast, the fishery takes place from October to January at a number of known spawning grounds. Overall, the protracted spawning period of the two components extends from October through to January, with annual variation of up to 3 weeks. Spawning occurs in successive waves in a number of well-known locations. These include large spawning grounds (VIIg & VIIaS) and small highly localised spawning beds in Division VIIj.

The stock structure and discrimination of herring in this area is not fully understood. It is known that fish in the eastern Celtic Sea recruit from nursery areas in the Irish Sea and tagging studies have shown linkages between these areas also. For the purpose of stock assessment and management these areas have been combined since 1982. For a period in the 1980s, egg and larval surveys were conducted for herring in this area. However, since 1989, acoustic surveys have been carried out, and currently are the only tuning indices available. In the Celtic Sea and VIIj, herring acoustic surveys have been carried out since 1989, and the current survey is the 17th in the series. In spring 2007, a herring larval survey is scheduled to take place in the Celtic Sea in a bid to determine young fish recruitment from larval abundance.

The 2006 autumn survey is the most comprehensive survey carried out in the current time series. The geographical extent of the annual 21 day survey was extended further offshore to include areas to the south of the main coastal spawning grounds to target winter spawning fish on an inward spawning migration. Spatial resolution of acoustic transects were increased over the entire south coast survey areas, with a special focus on spawning grounds throughout the survey confines. The acoustic component of the survey was complimented by a continuation of the detailed hydrographic work first established in the Celtic Sea in 2004.

Materials and Methods

Area coverage

Area coverage during the autumn 2006 survey started in the southwest at Loop Head (Figure 1) at the mouth of the Shannon Estuary (Division VIIb) and extended along the southwestern seaboard covering the main bays and inlets (VIIj). The south coast was covered in continuity from Mizen Head to Carnsore Point (VIIg and VIIaS). The survey was divided into 28 strata for the purposes of integration (Figure 1, Table 1). A parallel transect design was adopted for the main broad scale survey; with transect resolution set at 4nmi (nautical miles) for areas of low historic herring abundance in Divisions VIIb & VIIj (O'Donnell *et al,* 2004 and O'Donnell *et al.* 2005a & 2005b). Zigzag transects were used to maximise coverage in southwestern bays and inlets. Transects ran perpendicular to the coastline and lines of bathymetry wherever possible. Along the south coast, transect resolution was increased to 2nmi for areas of higher historic abundance (Divisions VIIg & VIIaS). Offshore coverage in the Celtic Sea extended out to 78nmi to take in offshore areas such as the "Trench" trawl grounds and the Labadie Bank.

A detailed survey of autumn spawning grounds was undertaken after the main broad scale survey was complete. Spawning grounds were surveyed working in an east to west progression using either 1nmi parallel transects for larger grounds or detection using the vessels sonar for discreet spawning beds. Schools were identified in discreet spawning beds and were surveyed using a cross-hairs transect approach as described by Doonan *et al.* (2003)

A total of 2,901nmi of integrateable acoustic data was collected during both survey components, relating to a distance travelled of some 3,382nmi for the 21-day survey.

Acoustic data Acquisition

Equipment settings for the acoustic equipment were determined before the start of the survey program and were based on established settings employed by FSS on previous surveys. The settings used on the *Celtic Explorer* acoustic array are detailed in Table 2.

Acoustic data were collected using the Simrad ER60 scientific echosounder. Simrad split-beam transducers of 18, 38, 120 and 200 KHz are mounted within the vessels drop keel and lowered to the working depth of 3m below the vessels hull or 8.8m subsurface.

While on the survey track the vessel was cruising using DC twin electric motor propulsion, supplied from 1 main diesel engine, in effect providing "silent cruising" as compared to normal operations (Anon, 2002). However, it should be noted that during fishing operations normal 2 engine operations were employed to provide sufficient power to tow the net.

Acoustic data were observed and recorded onto the hard-drive of the processing unit using the equipment settings from previous surveys. The “RAW files” were logged via a continuous Ethernet connection as “EK5” files to the vessels server and the ER60 hard drive as a backup in the event of data loss. In addition, as a further back up a hard copy was stored on DVD. Sonar Data’s Echoview® Echolog (Version 3.2) live viewer was used to display the echogram during data collection to allow the scientists to scroll through echograms noting the locations and depths of fish schools. The equipment was monitored continually by a member of the scientific crew. A log was kept recording time, position from the vessels GPS for the start and end point of each integrateable transect. This log was used to monitor the time spent off track during fishing operations and hydrographic stations plus any general observations.

Sonar observations

Whilst on survey track a watch was maintained on the sonar (Simrad SP70 long-range, low frequency omni sonar). The purpose being to determine the presence of inwardly migrating herring schools occurring outside of the acoustic transects. Settings established from previous were surveys were applied (Range: 1500m, tilt angle: -3°, frequency: 29KHz). Schools identified off track were further investigated using the vessels keel mounted ER60 echosounder. If of sufficient size, two transects were run crossing the school at right angles in a bid to determine school dimensions. These data were then partitioned using Echoview as previously described.

Analysis of acoustic data collected from off track observations was carried out following the methods developed by Doonan *et al.* (2003).

Calibration of Acoustic equipment

Calibration of the acoustic array was carried out following the principles as described by Foote *et al.* (1987). Calibration of the ER60 was carried out in Dunmanus Bay Co. Cork on the 5th October. The appropriate calibration correction factor was applied to the data before the final biomass was calculated. Calibration results fell within the boundaries expected and no irregularities were identified between previous calibrations. The acoustic array was last calibrated in May 2006.

The 38 KHz transducer was calibrated along with the following frequencies, 18, 120, 200 KHz. The 18 and 38 KHz frequencies were calibrated using standard target copper spheres (63mm and 60mm respectively). The 120 and 200 KHz frequencies were both calibrated using a 38.1mm tungsten carbide standard target sphere. The generated biomass data presented here were generated solely from data acquired through the 38 KHz transducer. The higher (120 and 200 KHz) and lower (18 KHz) frequency data was used primarily for non-quantitative species recognition at this time.

Biological Sampling

A single pelagic midwater trawl with the dimensions of 19m in length (LOA) and 6m at the wings ends and a fishing circle of 330 m was employed during the survey (Figure 19). Mesh size in the wings was 1.6 m through to 20 mm in the cod-end lining. The net was fished with a vertical mouth opening of 11 m, which was observed using both a cable linked "BEL Reeson" netsonde (50 kHz). The net was fitted with a Scanmar depth sensor. Spread between the trawl doors was monitored using Scanmar distance sensors, all sensors being configured and viewed through a Scanmar Scanbas system.

All components of the catch from the trawl hauls were sorted and weighed; fish and other taxa were identified to species level. Fish samples were divided into species composition by weight. Species other than herring were weighed as a component of the catch. Length frequency and length weight data were collected for each component of the catch. Length measurements of herring, sprat and pilchard were taken to the nearest 0.5 cm below. Age, length, weight, sex and maturity data were recorded for individual herring within a random 100 fish sample from each trawl haul. All herring were aged onboard. The appropriate raising factors were calculated and applied to provide length frequency compositions for bulk catches.

Decisions to fish on particular echo-traces were largely subjective and an attempt was made to target marks in all areas of concentration not just high-density shoals. No bottom trawl gear was used during this survey. However, the small size of the midwater gear used onboard and its manoeuvrability in relation to the vessel power allowed samples at or below 2m from the bottom to be taken in areas of clean ground.

Acoustic data analysis

Acoustic data were backed up every 24 hrs and scrutinised using Sonar data's Echoview® (V 3.2) post processing software for the previous days work. Partitioning of data into the below categories was largely subjective and was viewed by a scientist experienced in viewing echograms. Biological information was then applied directly to individual schools where possible. When no directed fishing had taken place on a school then a nearest neighbour approach was adopted.

The NASC values from each log interval were partitioned into the 4 categories after inspection of the echograms. Categories identified on the basis of trace recognition were as follows:

1. "Definitely herring" echo-traces or traces were identified on the basis of captures of herring from the fishing trawls which had sampled the echo-traces directly, and on large marks which had the characteristics of "definite" herring traces (i.e. very high intensity (red), narrow inverted tear-shaped marks either directly on the bottom or in mid-water and in the case of spawning shoals very dense aggregations in close proximity to the seabed).

2. "Probably herring" were attributed to smaller echo-traces that had not been fished but which had the characteristic of "definite" herring traces.

3. "Herring in a mixture" were attributed to NASC values arising from all fish traces in which herring were thought to be contained, owing to the presence of a proportion of herring within the nearest trawl haul or within a haul which had been carried out on similar echo-traces in similar water depths.

4. “Possibly herring” were attributed to small echo-traces outside areas where fishing was carried out, but which had the characteristics of definite herring traces.

The “EK5” files were imported into Echoview for echo post-processing. The echograms were divided into cells using a distance grid of 1nmi. Cells define sets of sample values of an echogram, from which integration variables can be calculated through echo integration. Echo integration was performed by selecting marks or scatter, which belonged to one of the four categories above. Regions were drawn around the various marks and the software calculates NASC values for the selected regions. NASC values were obtained by drawing regions around schools and then defining the regions as one of the four categories. The echograms were analysed at a threshold of -70 dB and where necessary plankton was filtered out by thresholding at –65 dB.

The allocated echo integrator counts (NASC values) from these categories were used to estimate the herring numbers according to the method of Dalen and Nakken (1983).

The following TS length relationships used were those recommended by the acoustic survey planning group (Anon, 1994) and Svellingen and Ona (1999)*:

Herring	TS = 20logL – 71.2 dB per individual (L = length in cm)
Sprat	TS = 20logL – 71.2 dB per individual (L = length in cm)
Mackerel	TS = 20logL – 84.9 dB per individual (L = length in cm)
Horse mackerel	TS = 20logL – 67.5 dB per individual (L = length in cm)
Pilchard*	TS = 20logL – 66.4 dB per individual (L = length in cm)

The TS length relationship used for gadoids was a general physoclist relationship (Foote, 1987):

Gadoids	TS = 20logL – 67.5 dB per individual (L = length in cm)

The analysis produced density values of numbers and biomass per nautical mile squared for each transect. The survey area was stratified into 28 strata using analysis areas with pre-determined boundaries. Inshore intertransects and offshore connecting transects were not included in the analysis. Area calculations of herring distribution within survey strata were calculated using R code statistical scripting.

Abundance estimate were generated using length-weight relationships determined from all trawl samples taken during the course of the survey.

Herring weight (grams)	= $0.0795^* L^{2.298}$ (L = length in cm)
Sprat weight (grams)	= $0.0030^* L^{3.404}$ (L = length in cm)
Pilchard weight (grams)	= $0.0013^* L^{4.3132}$ (L = length in cm)
Horse mackerel weight (grams)	= $0.0175^* L^{2.790}$ (L = length in cm)
Mackerel weight (grams)	= $0.0052^* L^{3.116}$ (L = length in cm)

Hydrographic data collection

Hydrographic stations were carried out during the survey at predetermined locations along the acoustic track (Figure 2 & 8). Data on temperature, depth and salinity were collected using a Seabird 911 rosette sampler from 1m subsurface to 5m above the seabed. Post-processing of hydrographic data was carried out using SBE DataProcessing and Ocean Data View©.

In addition to vertical CTD casts, horizontal profiling of surface waters (5.5m subsurface) was collected during the survey providing salinity and temperature profiling.

Marine Mammal and Seabird Observers

During the survey an observer kept a daylight watch on marine mammal and seabird sightings from the crow's nest (18m above sea level).

During cetacean observations, watch effort was focused on an area dead ahead of the vessel and 45^{o} to either side using a transect approach. Sightings in an area up to 90^{o} either side of the vessel were recorded. The area was constantly scanned during these hours by eye and with binoculars. Ships position, course and speed were recorded, environmental conditions were recorded every 15 minutes and included, sea state; visibility; cloud cover; swell height; precipitation; wind speed & wind direction. For each sighting the following data were recorded: time; location; species; distance; bearing; number of animals (adults, juveniles and calves) and behaviour. Relative abundance (RA) of cetaceans was calculated in terms of number of animals sighted per hour surveyed (aph). RA calculations for porpoise, dolphin species and minke whales were made using data collected in ≤ Beaufort sea state 3. RA calculations for large whale species were made using data collected in ≤ Beaufort sea state 5.

Results

Herring stock size

Herring	Millions	Biomass (t)	% Contribution
TSB Estimate			
Definitely	214.9	26,325	70.7
Mixture	39.8	4,627	12.4
Probably	50.8	6,305	16.9
Total estimate	305	37,256	100
Possibly		510	
Possible estimate	305	37,766	
SSB Estimate			
Definitely	206.5	25,496	70.9
Probably	48.8	6,126	17.0
Mixture	36.9	4,352	12.1
SSB estimate	292	35,974	100

The TSB (total stock biomass) estimate is composed of over 70% of echotraces categorised as "definitely" herring. Of this, almost 91% of schools were observed within 20nmi from the coast (Figure 3, Tables 3 & 11). Both the TSB and SSB (spawning stock biomass) estimates were generated from a total of 85 single herring echotraces. Of which, 61 schools were categorised as "definitely" herring and a further 24 schools as "probably" herring from a total of 226 transects surveyed. The mixed schools category accounted for some 60 schools overall.

A breakdown of the herring estimate is provided by age, (Figure 6, Tables 5-7), maturity (Figure 6, Tables 8& 9) and distribution (Figure 3 and Table 3 & 11).

Herring distribution

A total of 34 trawl hauls were carried out over the course of the survey (Figure 2 & Table 3). Of this, 52% contained herring at over 50% by weight of bulk catch.

Broad scale survey

In the Shannon region ICES divisions VIIb and VIIj (Strata 1 & 2) few single low-density herring echotrace were identified, contributing just over 4% to the TSB (Figure 3 and Table 11). These schools were found to contain pre-spawning herring of maturity stage 3; indicating spawning was still some way off. No other herring biomass was encountered in this region. The lack of herring could be a consequence of a mismatch in timing, as historically this area has contributed a greater proportion to the overall herring abundance of the survey.

The southwestern region contributed no herring to the overall estimate (Figure 3, Table 11). Historically, this area yields the greatest abundance of juvenile herring, most notably from the bays and inlets that are known as important nursery areas. Indeed, juvenile herring are often encountered in bays mixed with sprat schools, which were also notably absent from this years coverage of the area (Figure 3 & 6, Table 10). Sprat distribution is known to exhibit large inter-annual variation both temporally and spatially.

Overall, little herring biomass of significance was encountered outside of inshore spawning areas as compared with the 2005 survey. Sprat and pilchard occurrence were also significantly down on the previous year. Herring were encountered during the broad scale survey, appearing in mixed schools over a relatively small geographical area (Table 3 & 11). The 'herring in a mixture' category contributed just over 12% to the final TSB estimate. Offshore transects in the Celtic Sea (Strata 9) yielded no single large herring schools as compared to the same area the previous year, this would indicate the bulk of the stock at this time was well contained within the inshore survey area and indeed the spawning areas. Maturity staging indicated individuals to be in a pre-spawning state (3-4) and thus a more likely component of the winter spawning stock. No evidence of autumn spawning fish was found.

Overall, just over 18% of the herring TSB was distributed within broad scale survey area. This is in contrast to the same time period in 2005 when the majority of the TSB was found to be located at least 15nmi from the coast and out to 65nmi offshore.

Spawning box survey

Traditional inshore herring spawning areas along the south coast were found to contain the greatest herring biomass from this years survey, contributing some 77% to the TSB (Table 11), with 71% of the TSB being assigned to the definitely herring category. Moreover, as only a small proportion of the TSB was assigned to the probably (17%) or possibly (<2%) categories a high degree of confidence can be placed in the overall estimate.

The Ballycotton area (strata 14) was found to contain the greatest biomass of herring (17,600t) contained within the 30 schools (Figure 3, Table 11). The Daunt area (strata 15) also produced a significant number of schools (25) but of smaller biomass, contributing 18% to the final TSB. Both Baginbun and the Brow (strata 11 and 17) spawning boxes yielded a herring biomass of 6% and 3% of the TSB respectively.

Overall, herring within the spawning boxes were well distributed as medium to large schools over the grounds (Figure 3, Table 11). In the 2005 survey, a small number of very large schools made up the estimate. This may be a consequence of the moderate wind and swell conditions encountered during the inshore section of the survey or the fact that the fishery was closed, or indeed a combination of both.

Sonar observations

In total 4 off track schools were investigated from sonar observations. This breaks down as follows: 2 schools identified as herring in the Baginbun spawning box (strata 11), one school containing herring during the spawning box survey in Dunmanus Bay (strata 19) and a school identified as mackerel from strata 10.

The identification of fish schools on sonar from bottom features at distance from the vessel is a specialised skill. In a bid to reduce time spent off track investigating artefacts it was decided to focus effort on offshore areas of deeper waters and inshore spawning grounds. In offshore areas the ground type favoured the ease of identification of large schools; water depth >70m and over a clean soft substrate. Effort was focused on this area to try to locate inwardly migrating schools, with little success. However, no herring schools were found. On inshore spawning grounds where the bathymetry is uneven and often interspersed with boulders and outcrops, picking out individual schools from bottom features is much more difficult. An experienced member of the scientific crew maintained a sonar watch during spawning box surveys.

The analyses of these data are currently being undertaken and were not presented in this report as it was deemed they would contribute little to the overall estimate.

Herring stock composition

Age analysis indicates the stock to be composed of ages between 0-6 winter rings (Figure 6, Table 5 & 10). The dominant year class overall was the 2 ringers of the 2003/2004 year class, by weight (65.7%) and by numbers (68.9%). The second and third most abundant were the 3 and 1-winter ring fish accounting for 17.5% and 5.9% by weight and 15.7% and 6.9% by numbers respectively (Tables 6, 7 & 10).

The lack of 0 and 1-winter ring fish is evident from the survey results and commercial samples; also evident is the lack of older (3-winter ring) fish. This emphasizes the fragility of the stock in terms of the number of supporting cohorts. Incoming year classes (0 and 1) appear weak and will do little to bolster the current state of the stock as older year classes succumb to the fishery.

Mature fish dominated the survey stock, by both weight and by numbers (Tables 8 & 9). The SSB made up over 95% of the total herring biomass encountered. Pre-spawning fish dominated the estimate (Figure 6, Tables 8 & 9), indicating peak spawning had yet to take place. Indeed no actively spawning or spent fish were encountered during the survey. This would also indicate the lack of autumn spawning fish and the dominance of winter spawners overall.

Percentage length frequencies derived from trawl samples that were used to generate the survey stock profile are shown in Table 4.

Secondary target species

Mackerel

Mackerel distribution was highest in the Celtic Sea from Cork to Waterford Harbour. Smaller amounts were observed in the Dingle Bay area and in the southwest (Figure 4). In total mackerel were taken in over 73% of hauls (Table 3). The size distribution of mackerel taken from catches indicated individuals to be within the 0-1 group, with lengths of 18-19cm respectively.

No biomass for mackerel was generated from this year’s acoustic data due to uncertainties in the validity of the estimate. Single mackerel high-density marks were observed around the Old Head of Kinsale and the area east of Mine Head. The highest concentrations were observed in offshore waters some 25-40nmi offshore (Figure 7c).

This is very similar to the distribution pattern observed for the same time period in 2005 and in 2004. However, it should be noted that mackerel schools from the 2005 survey were made up of 2-3 group fish.

Scad

Scad (Horse mackerel) were found in a number of areas within the southwest and as mixed schools with herring in an area southwest of Waterford Harbour (Figure 5 & 7e respectively). However, it should be noted that the 'mixture' contribution to the total biomass estimate is not represented in the graphic of scad distribution in Figure 5. Overall, scad were represented in 17% of survey hauls (Table 3). Scad catches were composed of individuals between 23-36cm, the most dominate length class modes encountered occurred at 26 and 28cm respectively. In total some 19 schools of scad were encountered (Table 13), of this 12 were attributed to the 'definitely' category making up 35% of the total scad biomass or 2,200t. The largest proportion of the estimate was attributed to the 'mixture' category, over 47% of total or 3,000t. This was taken from strata 12 in the southeast. The remaining 17% of the total estimate or 1,100t was attributed to the 'probably' category and came from strata 5 in the southwest. Small amounts of scad were taken as mixed catches with herring in strata 9 & 10 but contributed little to the overall estimate of biomass.

The distribution of scad around the southwest region is consistent with the results of previous surveys. The commercial fishery takes place in this area in quarter 4 targeting scad schools occurring along the 70-100m contours.

Scad	Millions	Biomass (t)	% contribution
TSB Estimate			
Definitely	12.0	2,237	35.2
Mixture	17.2	3,011	47.4
Probably	5.9	1,104	17.4
Total estimate	35	6,352	100

Hydrography

A total of 38 hydrographic stations were carried out on 8 long-shore and cross-shore transects. The main north south CTD transects (Figure 8, coloured transects) were carried out at Kinsale, Ram Head and Baginbun. Secondary smaller transects were carried out in areas of known herring distribution to determine the oceanographic conditions relating to herring presence (Figure 8, indicated as black dots).

Physical oceanography

The first CTD cast in Dunmanus Bay was carried out in order to acquire a sound velocity profile for the acoustic calibration, while the main hydrographic data collection took place off the south coast (Figure 8). Four north-south transects of about 45 nm were completed, and two east-west long-shore transects, one at about 10 nm offshore at ~65 m depth, and one at 45 nm offshore in ~90 m average water depth. The gaps between transects were filled in with single stations for increased horizontal resolution of water properties. Stations spacing along the transects was on average 9 nm (11 nm on the outer east-west transect), with most stations occurring in depths of between 50 and 100 m.

The horizontal distribution of temperature and salinity at 3 m depth showed very cold and fresh surface water due to river runoff in the bays of Kinsale, Cork harbour and Ballycotton (Figure 9). In the northeastern corner of the survey area, near Baginbun, the low temperatures were seen over a larger area than the relatively small river plume defined by the salinity signal. The coldest and least saline surface water overall was found east of Cork harbour in Ballycotton. The salinity and temperature distribution in the upper ~10 m were patchy, as the cool fresh surface water formed a lens of varying thickness and horizontal extension. A band of warmer and more saline water separated the fresh water near the coast from low surface salinities near the southern end of the survey area, around 51°N.

On the north-south transect along ~8° 30’W from Kinsale to ~50° 50'N, there was a sharp thermocline at about 40 m depth outside of about 20 km from the start of the transect (Figure 10). On the inshore end of the transect the water column appeared well mixed beneath the river plume and a freshwater surface lens was identified further offshore.

On the Ram Head transect (7° 36’W; Figure 8 & 11) the coastal conditions appeared weakly stratified. The thin freshwater cap observed at Kinsale was still evident in Ballycotton but extended further offshore. The Baginbun transect (6° 47’W) was the warmest and the most weakly stratified (Figure 12). The river plume did not extend far from the transect start but there was another isolated lens of fresh surface water, overlying a patch of warm and saline water at the intermediate depth. The outer, long-shore transect shows the gradual change from west to east, which might be influenced by deeper water from the Atlantic.. In the western part of the survey area there is colder saline water below a sharp thermocline leading to more mixed conditions in the east (Figure 13).

Overall, a very sharp thermocline was present at the offshore stations, usually at about 40 m depth, separating the relatively warm water (mean ~15°C) in the shallow well-mixed layer from the cooler (~10°C) temperatures in the deeper water. There was also marked change in salinity from an average of 34.8 above the seasonal thermocline to >35.2 below it. Closer to shore, the stratification was weaker except for the freshwater input in the uppermost metres of water; the eastern part of the survey area was also more weakly stratified than the western.

Biological oceanography

Vertical NASC values were superimposed onto four temperature and salinity plots to examine whether there were any spatial links between the vertical distribution of the different fish species and their environment (Figures 14-17). Most established herring spawning grounds are situated in the inshore bays, which are in most influenced by lower temperatures and decreased salinity due to freshwater dilution. However, the horizontal distribution of fish did not seem to be strongly linked with any spatial trends in temperature or salinity from this years findings.

Herring schools showed little correlation with physical oceanographic conditions in this instance. Due to the well-mixed nature of the water column in many inshore areas containing fish echotraces any discernable evidence was difficult to infer. As could be the case, especially in the more shallow water spawning sites, such as Baginbun and Ram Head (Figures 15 & 17 respectively) spawning site selectivity maybe more closely related physical features such as bottom topography and substrate type. In combination with ambient oceanographic conditions at the time of spawning, including current fronts, this may be more of a consequence of spawning bed selection than purely oceanographic conditions alone. However, for the Tramore transect (Figure 16) where a large single herring mark was observed, herring did appear to be occupying a temperature boundary layer area between 13.5-14.5°C, this region showed a slightly reduced boundary in relative salinity. From this one observation it is hard to evaluate whether this is the preferred habitat or merely a consequence of active migration or movement. Maturity analysis showed the majority of herring were pre-spawning and so no doubt conditions will have changed during actual spawning events.

Looking at horizontal surface temperature and salinity data (Figure 9) herring distribution did appear to be more strongly correlated with cooler water areas occurring at 3m subsurface. Surface salinity did not appear to be determining presence or absence as schools were located in both lower and upper ends of the range encountered. Mackerel distribution tended to favour cooler surface water and temperature boundary areas (Figure 4& 9) and larger schools appear to favour full seawater conditions. As a sharp thermocline was evident at 40m, schools encountered more than 5nmi offshore would be influenced by this horizontal boundary region.

Overall, the vertical resolution of the acoustic data and hydrographic data combined proved little for most transects especially in shallow inshore spawning areas where herring distribution is greatest at this time of year. For horizontal sea surface data little can be drawn from the distributions recorded at this time.

Marine Mammal and seabird observations

A total of 114.68 hours of survey time were logged in total, with 40.73 hours (35.5%) in Beaufort sea state three or less. 77 sightings of three cetacean species, totalling 1108 individuals were recorded (Figure 18).

During calibration procedures in Dunmanus Bay (5 October), no survey effort was conducted. On 6 October no survey effort was conducted due to severe weather conditions (winds gusting to 90kph, twinned with 5m high seas).

The three species of cetacean recorded were; common dolphin (*Delphinus delphis*), minke whale (*Balaenoptera acutorostrata*) and fin whale (*Balaenoptera physalus*). Two sightings of unidentified dolphins were made (both were thought to be common dolphins) and seven unidentified whales (blows) were sighted (all were thought to be fin whales).

Common dolphin was the most frequently sighted species, accounting for 74% of all sightings. Group size ranged from 5 – 80 animals. Common dolphins were most frequently encountered off the south coast, where they were most abundant over the Labadie Bank. Seven minke whale sightings were made and they were the most frequently sighted whale species. All minke whale sightings occurred off the south-west coast, with highest abundance occurring in Dingle Bay. Maximum group size for minke whales was two animals.

Five confirmed fin whale sightings were made, though six sightings of unidentified whale blows were also thought to be of this species. Fin whale sightings occurred off the south-west and south coasts. All sightings were of single animals.

For the majority of cetacean sightings off the south-west coast, cetaceans exhibited feeding behaviour (often feeding in association with gannets). Off the south coast, feeding activity was noted inshore in many areas, however feeding activity was not as frequently encountered as off the south-west coast. Despite the high abundance of common dolphins over the Labadie Bank, no feeding activity was noted in the area.

Overall large whale activity was more noticeable than in 2005, however the large aggregations of feeding whales encountered off the south coast in 2004 were not present. The lack of the large sprat schools seen in 2004 may account for the lack of whale aggregations and generally low numbers of fish marks were noted over most of the survey area. However where fish were present (as off the south-west coast) feeding aggregations did occur.

Cetacean Bycatch

Common dolphins were bycaught in the trawl on two occasions during the survey. On both occasions trawling was being conducted at night (03:50 and 00:35 respectively) and on each occasion, two animals were caught. Despite the very short duration of the sampling trawls (15 minutes from doors in the water to commencement of hauling in both cases) the animals were landed dead and showed no eye or blowhole reflex when tested. On both occasions the animals were found in the cod end.

It is hypothesised that the animals were in the trawl feeding (one animal being found with herring in its throat), became disorientated in the net and were trapped in the confined space of the cod end. Unable to manoeuvre out of the cod end the animals appear to have panicked, inhaled water (three of the animals had froth emanating from the blow hole) and drowned. The only injuries evident on the four animals were scratches and cuts to the tip of the beak and the tail flukes.

It is thought that common dolphins are particularly vulnerable to getting caught in trawls at night when they have difficulty seeing the net and are unable to visualise it acoustically due to its low sound reflectivity. Trapped animals appear to panic, inhale water and drown rapidly. Bycatch in pelagic trawling for herring has not been found to be a problem in past studies however a bycatch of one animal in the 2004 herring acoustic survey and this years bycatch of four animals suggest that a review of the current level of bycatch in the commercial fishery may be prudent (as trawls in this fishery are larger than those used in the current survey).

It is hoped that some measures to help in avoiding dolphin bycatch can be trialled in future surveys. New pinger trials due to be conducted in 2007 may provide an working acoustic deterrent for common dolphin, while trials with separator grids in the UK have yielded some success.

For all bycaught animals; animals were photographed, sexed, measured and genetic (skin) samples and teeth samples were taken.

Seabirds

19 species of seabirds were encountered during the survey. Species seen were; Lesser Black Backed Gull (*Larus fuscus*); Great Black Backed Gull (*Larus marinus*); Herring Gull (*Larus argentatus*); Black Headed Gull (*Larus ridibundus*); Great Skua (*Stercorarius skua*); Pomerine Skua (*Stercorarius pomarinus*); Parasitic Skua (*Stercorarius parasiticus*); Gannet (*Morus bassanus*); Manx Shearwater (*Puffinus puffinus*); Great Shearwater (*Puffinus gravis*); Sooty Shearwater (*Puffinus griseus*); Kittiwake (*Rissa tridactyla*); Fulmar (*Fulmarus glacialis*); Storm Petrel (*Hydrobates pelagicus*); Guillemot (*Uria aalge*); Razorbill (*Alca torda*); Shag (*Phalacrocorax aristotelis*); Cormorant (*Phalacrocorax carbo*); Common Tern (*Sterna hirundo*).

The most commonly encountered species were gannet, kittiwake and lesser black backed gull.

During foggy weather a number of passerine and wader species were encountered on or around the ship.

Discussion

Overall, the survey was very successful, with little time was lost due to adverse weather. The survey was completed in its entirety and due to favourable weather an extended area of coverage was undertaken. Extensive trawl sampling was carried out and complemented by comprehensive hydrographic coverage.

The stock was well contained within the survey area, with fish distribution concentrated close inshore. The lack of actively spawning or spent fish would indicate spawning had yet to take place in any significant amount. Sea surface temperature data indicate the upper 5m of the water column to be on average 1°C higher than at the same time last year. This increased temperature may be linked to the delayed onset of spawning as compared to the same time period last year. This warmer surface water may also be linked to lack of sprat abundance in the southwest and western Celtic Sea, an area normally associated with high sprat abundance.

Herring spawning migrations are known to take place in successive waves in the Celtic Sea. In 2005, herring schools were found distributed from inshore, where active spawning was taking place, to further offshore. Actively migrating pre-spawning schools were located 30 and 60nmi offshore forming the secondary and tertiary spawning waves. Compared to 2005 it was unusual to find almost the entire biomass of herring distributed within 15nmi of the coastline in a pre-spawning state (stage 4) and no secondary or tertiary waves evident offshore. Existing offshore strata were further extended south in a bid to locate a second wave of migrating pre-spawners without success. The extension area included offshore summer feeding grounds some 78nmi offshore where the quarter 3 fishery takes place. As the commercial inshore fishery was closed at the time of the survey no direct comparison with commercial catch samples could be made for size or maturity comparisons of individuals.

The biomass estimate of herring generated from the survey reflects the stock age structure as revealed from sampling of commercial landings data. In both instances the dominance of 2-winter ring fish is clearly evident. What are also evident are the weakness of the 0-1-winter ring year classes and the lack of older years classes within the fishery. As the SSB estimate for this stock is not used in the ICES stock assessment process due to poor model diagnostics, the abundance at age of the stock is scrutinised (2 –5-winter rings only). As the results from this survey indicate that almost 69% of the stock is made up of a single year class. As little biomass was found outside of the spawning grounds, it could be hypothesized that the entire stock was contained within the survey area in the Celtic Sea. Moreover, a change in spawning migration behaviour as a defence mechanism brought on by reduced stock size and fishing pressure may well occurring in the Celtic Sea. Adequate steps therefore need to be taken to ensure the stock is allowed to recover, as recommended by HAWG in 2006. In the current situation this stock is harvested both during spawning and summer feeding phases without adequate respite during each successive season.

Acknowledgments

We would like to express our thanks and gratitude to Ciaran Flanagan and crew of the Celtic Explorer for their good will and professionalism during the survey. We would like to thank all the skippers who provided up to date position information on the whereabouts of herring schools during the survey. We would also like to thank Frankie Griffin (Gear Consultant) for his help and invaluable advice on the fishing gear and local knowledge of the spawning grounds.

Participants List

Name	Capacity	
Ciaran O'Donnell	Cruise Leader	
Ian Doonan	Acoustics	
Deirdre lynch	Acoustics /herring aging	
Afra Egan	Acoustics	
John Boyd	Biologist	(Deck Scientist)
Dermot Fee	Biologist	
Orla Hanniffy	Biologist	
Noirin Burke	Biologist	(GMIT)
Dave Wall	Marine Mammal Observer	(IWDG)
Jenny Ullgren	Oceanographer	(NUIG)

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Table 1. Survey Strata for Celtic Sea and VIIj herring acoustic survey, October 2006.

Strata	Name	Transect	Transects	Type	Area (nmi^2)	Total Transect length (nmi)
1 (a & b)	SW Shannon	Parallel	14	Broad scale	726.4	150.5
2	Inside Shannon	Zigzag	6	Broad scale	41.8	37.92
3	Dingle Bay	Zigzag	9	Broad scale	122.7	80.32
4 (a & b)	SW Corner	Parallel	8	Broad scale	581.6	147.45
5	Kenmare Bay	Zigzag	7	Broad scale	52.1	44.49
6	Bantry Bay	Zigzag	9	Broad scale	32.6	38.36
7	Dunmanus Bay	Zigzag	5	Broad scale	5.6	14.38
8	Mizen Area	Parallel	14	Broad scale	683.3	190.87
9	Offshore C S	Parallel	32	Broad scale	2075.7	955.43
10 (a,b,c,d,e)	Inshore C S	Parallel	29	Broad scale	1064	546.41
11	Baginbun	Parallel	9	Spawning box	34.6	38.73
12	Tramore	Parallel	17	Spawning box	92.5	99.62
13	Waterford Hbr	Zigzag	6	Broad scale	3.8	23.97
14	Ballycotton	Parallel	15	Spawning box	86.3	96.07
15	Daunt	Parallel	13	Spawning box	58.1	62.03
16	Stags	Parallel	5	Spawning box	1.7	8.35
17	Brow	Parallel	12	Spawning box	1.5	26.4
18	Dunmanus _S	Cross Hairs	2	Spawning box	1.4	na
19	Dunmanus _N	Cross Hairs	2	Spawning box	0.6	na
20	Poleen	Cross Hairs	2	Spawning box	0.2	na
21	Bantry	Cross Hairs	2	Spawning box	0.9	na
22	Garnish	Cross Hairs	2	Spawning box	1.6	na
23	Dingle_S	Parallel	6	Spawning box	9	9.52
24	Dingle_N	Parallel	6	Spawning box	5.3	7.91
25	Kerry Head	Parallel	12	Spawning box	60.6	62.57
26	Kilbaha	Cross Hairs	2*	Spawning box	2.8	na
27	C.S Extension	Parallel	10	Broad scale	200	108.6
28	Labadie Bank	Parallel	12	Broad scale	325	151.3
		Total	**266**	**Total**	**6272**	**2901***

* : Integratable acoustic mileage

na: No visible signs of fish schools when investigated or not covered.

Table 2. Settings for the Simrad ER60 echosounder, employed during the Celtic Sea and VIIj herring acoustic survey, October 2006.

Echo sounder:	Simrad ER 60
Frequency:	38 kHz
Transducer:	ES 38B- Serial
Absorption Coefficient:	0.067 dB/Km (manual)
Pulse length:	1.024 m/s
Bandwidth:	2.425 KHz
Transmitting Power:	2000 W (Max)
Angle Sensitivity:	13.9 dB
2- way beam angle:	-21.69°
Gain:	25.55
S_A Correction:	-0.65
3 dB Beam Width:	
Alongship:	6.39°
Athwartship:	6.67°
Max Range:	500m

Table 3. Celtic Sea herring acoustic survey 2006. Position, water depth, depth of trawling and percentage species composition of fishing hauls. (* denotes: non pelagic catch component).

No.	Date	Lat.	Lon.	Time	Bottom	Target	Bulk Catch	Herring	Mackerel	Scad	Sprat	Pilchard	Others*
		N	W		(m)	(m)	(Kg)	%	%	%	%	%	%
1	02.10.06	52 31.38	10 14.20	10:25	96	0	4.8				13.2		86.8
2	02.10.06	52 28.14	10 18.73	13:50	104	60	5.3			2.6	1.3		96.1
3	02.10.06	52 25.20	10 13.10	16:25	59	0	45.9		10.3				89.7
4	03.10.06	51 58.79	10 43.72	07:10	106	0	136	97.2	2.3				0.5
5	03.10.06	52 03.63	10 15.83	14:10	40	0	500		0.1	73.1		25.7	1.1
6	03.10.06	51 51.91	10 54.53	19:25	147	0	19		5.8	4.0		2.9	87.3
7	04.10.06	51 44.16	10 26.38	02:00	74	5	0						
8	04.10.06	51 39.00	10 07.00	07:35	60	17	200	0.3	17.6		67.0		15.1
9	04.10.06	51 40.08	10 37.05	11:50	121	20	500						100.0
10	04.10.06	51 28.30	10 32.05	19:40	141	0	295						97.8
11	07.10.06	51 18.56	08 15.44	15:35	98	58	0						
12	08.10.06	51 19.40	07 52.60	14:57	94	0	0						
13	10.10.06	51 28.36	07 23.12	09:00	97	0	40.3	44.5	37.2	17.2			1.1
14	11.10.06	51 43.32	07 00.12	10:47	76	5	411.6		100.0				
15	12.10.06	51 54.91	06 45.09	11:30	67	10	500	63.9	33.1		3.0		0.1
16	12.10.06	51 56.93	06 50.37	15:12	61	0	300	5.2	84.5		0.4		9.9
17	12.10.06	52 08.05	06 47.55	23:05	30	0	376	95.8	4.2				0.1
18	13.10.06	51 51.27	07 10.39	10:50	78	0	159.5	0.6	82.4		14.1		2.9
19	13.10.06	52 05.14	07 15.61	23:15	43	0	1300	20.4	18.6	58.3	0.1	2.6	0.1
20	14.10.06	51 51.67	07 26.55	19:12	53	10	350		98.9				1.1
21	15.10.06	51 54.93	07 40.81	09:15	27	0	78.9		99.2			0.8	
22	15.10.06	51 49.73	07 46.01	12:30	63	0	300	97.6	0.8		0.1		1.5
23	15.10.06	51 49.17	07 49.08	15:22	48	0	200	63.3	28.8			3.8	3.0
24	15.10.06	51 47.97	07 50.85	18:30	53	0	2300	88.8	10.9			0.2	
25	16.10.06	51 44.73	08 12.57	20:10	26	6	2500	93.8	5.7			0.5	
26	17.10.06	51 40.85	08 23.25	02:09	36	5	400	37.2	58.1			0.4	4.4

Table 3 cont.

No.	Date	Lat. N	Lon. W	Time	Bottom (m)	Target (m)	Bulk Catch (Kg)	Herring %	Mackerel %	Scad %	Sprat %	Pilchard %	Others* %
27	17.10.06	51 37.38	08 26.33	03:44	43	5	156.5	92.6	5.9		0.4		1.1
28	17.10.06	51 36.61	08 18.09	11:45	64	0	500		94.8		5.2		
29	17.10.06	51 25.26	08 25.25	13:55	92	0	0						
30	18.10.06	50 34.60	08 06.36	22:52	65	20	16.72						100
31	19.10.06	51 26.58	09 23.74	14:22	62	0	180	0.3	98.6		1.1		
32	19.10.06	51 28.41	09 34.46	16:40	42	11	800	87.9	11.9			0.1	
33	20.10.06	51 32.12	09 51.70	00:35	65	5	64.9	64.6	32.5	0.01	2.3		0.6
34	20.10.06	52 01.83	10 12.66	10:00	39	0	18.4		98.9			1.1	

Table 4. Length frequency (%) of herring hauls used for calculating 'definitely' and 'probably' abundance. Celtic Sea and VIIj herring acoustic survey 2006.

Haul Length (cm)	4	13	17	22	24	25	26	27	32	15	22, 24-27	Total
14												**0**
14.5												**0**
15												**0**
15.5												**0**
16										1		**1**
16.5												**0**
17										1		**1**
17.5												**0**
18												**0**
18.5												**0**
19												**0**
19.5												**0**
20			1									**1**
20.5		1	2									**3**
21	1	1	4									**6**
21.5	2	3	7		1	2	1	1	1		1	**19**
22	1	10	17	2	5	6	5	2	3	3	4	**58**
22.5	2	12	9	5	12	9	13	7	4	5	8	**86**
23	3	21	14	12	21	17	21	16	4	6	17	**152**
23.5	4	17	11	12	15	18	17	18	5	18	16	**151**
24	5	16	11	18	16	15	12	17	5	14	16	**145**
24.5	10	6	6	7	5	11	7	10	5	10	8	**85**
25	11	7	5	12	12	7	8	11	8	13	10	**104**
25.5	12	1	2	8	2	7	3	6	8	8	6	**63**
26	10	2	2	7	4	3	4	4	8	5	5	**54**
26.5	9	1	3	5	3	3	4	2	15	6	3	**54**
27	9		2	7	3	2	2	2	16	6	3	**52**
27.5	9	2	1	2	1	1	1	2	11	2	2	**34**
28	6		1	3		1		1	6	1	1	**20**
28.5	4		1						2	1		**8**
29	1											**1**
Total	**99**	**100**	**99**	**100**	**100**	**102**	**98**	**99**	**101**	**100**	**100**	**1098**
%	**9.0**	**9.1**	**9.0**	**9.1**	**9.1**	**9.3**	**8.9**	**9.0**	**9.2**	**9.1**	**9.1**	**100**

Table 5. Herring Age length key from combined trawl samples. Celtic Sea and VIIj herring acoustic survey 2006.

Age (rings) Length (cm)	0	1	2	3	4	5	6	7	8	9	Total
14											**0**
14.5	1										**1**
15	3	1									**4**
15.5	2										**2**
16	10										**10**
16.5	8										**8**
17	3										**3**
17.5	1										**1**
18											**0**
18.5											**0**
19											**0**
19.5											**0**
20											**0**
20.5		1									**1**
21											**0**
21.5		2	2								**4**
22		6	21								**27**
22.5		5	32								**37**
23		4	62								**66**
23.5		9	94	8							**111**
24		1	72	8							**81**
24.5		2	40	15							**57**
25			37	31	5						**73**
25.5			28	20	1	1					**50**
26			6	26	5	7	1				**45**
26.5			6	14	4	6					**30**
27			2	11	13	13					**39**
27.5				3	12	10	1				**26**
28			1		7	3	2				**13**
28.5				1	2	1					**4**
29								1			**1**
Total	**28**	**31**	**403**	**137**	**49**	**41**	**4**	**1**	**0**	**0**	**694**
%	**4.03**	**4.47**	**58.07**	**19.74**	**7.06**	**5.91**	**0.58**	**0.14**	**0.00**	**0.00**	**100**

Table 6. Total biomass (000's tonnes) of herring at age (winter rings), by strata as derived from acoustic estimate of abundance. Celtic Sea and VIIj herring survey 2006.

Strata	0 rings	1	2	3	4	5	6	7	8	9	Total
1	-	-	0.5	0.4	0.3	0.2	-	-	-	-	**1.6**
2	-	-	-	-	-	-	-	-	-	-	**0**
3	-	-	-	-	-	-	-	-	-	-	**0**
4	-	-	-	-	-	-	-	-	-	-	**0**
5	-	-	-	-	-	-	-	-	-	-	**0**
6	-	-	-	-	-	-	-	-	-	-	**0**
7	-	-	-	-	-	-	-	-	-	-	**0**
8	-	-	-	-	-	-	-	-	-	-	**0**
9	-	0.3	2.8	0.4	0.1	0.1	-	-	-	-	**3.6**
10	-	0.1	1.9	0.8	0.3	0.2	-	-	-	-	**3.2**
11	-	0.3	1.4	0.3	0.1	0.1	-	-	-	-	**2.2**
12	-	0.1	0.8	0.1	-	-	-	-	-	-	**1**
14	-	0.9	12	3	0.8	0.7	0.1	-	-	-	**17.5**
15	-	0.3	4.8	1.2	0.3	0.2	-	-	-	-	**6.9**
16	-	-	-	-	-	-	-	-	-	-	**0**
17	-	-	0.4	0.3	0.3	0.2	-	-	-	-	**1.2**
23	-	-	-	-	-	-	-	-	-	-	**0**
24	-	-	-	-	-	-	-	-	-	-	**0**
25	-	-	-	-	-	-	-	-	-	-	**0**
Total	**0**	**2.2**	**24.5**	**6.5**	**2.1**	**1.7**	**0.2**	**0**	**0**	**0**	**37.3**
%	**0**	**5.9**	**65.7**	**17.5**	**5.7**	**4.7**	**0.4**	**0**	**0**	**0**	**100**

Table 7. Herring abundance (millions) at age (winter rings), by strata as derived from acoustic estimate of abundance. Celtic Sea and VIIj herring survey 2006.

Strata	0 rings	1	2	3	4	5	6	7	8	9	Total
1	0	0.35	4.07	3.06	1.80	1.41	0.16	0.04	-	-	**10.91**
2	-	-	-	-	-	-	-	-	-	-	**0.00**
3	-	-	-	-	-	-	-	-	-	-	**0.00**
4	-	-	-	-	-	-	-	-	-	-	**0.00**
5	-	-	-	-	-	-	-	-	-	-	**0.00**
6	-	-	-	-	-	-	-	-	-	-	**0.00**
7	-	-	-	-	-	-	-	-	-	-	**0.00**
8	-	-	-	-	-	-	-	-	-	-	**0.00**
9	-	3.24	24.27	3.09	0.54	0.40	0.04	-	-	-	**31.58**
10	0.35	0.95	15.33	5.54	1.60	1.34	0.10	-	-	-	**25.21**
11	-	3.28	12.36	1.92	0.66	0.52	0.05	-	-	-	**18.79**
12	-	1.09	6.83	0.81	0.10	0.08	0.01	-	-	-	**8.92**
14	-	8.87	103.8	22.06	5.33	4.35	0.34	-	-	-	**144.73**
15	-	3.13	40.89	9.09	1.92	1.56	0.14	-	-	-	**56.73**
16	-	-	-	-	-	-	-	-	-	-	**0.00**
17	-	0.23	3.04	2.25	1.56	1.36	0.13	-	-	-	**8.57**
23	-	-	-	-	-	-	-	-	-	-	**0.00**
24	-	-	-	-	-	-	-	-	-	-	**0.00**
25	-	-	-	-	-	-	-	-	-	-	**0.00**
Total	**0.4**	**21.1**	**210.6**	**47.8**	**13.5**	**11.0**	**1.0**	**0.0**	**0**	**0**	**305.42**
%	**0.1**	**6.9**	**68.9**	**15.7**	**4.4**	**3.6**	**0.3**	**0.0**	**0**	**0**	**100**
Cv (%)	**91.3**	**33.3**	**36.7**	**34.2**	**30.6**	**30.7**	**28.5**	**72.2**	**-**	**-**	**-**

Table 8. Herring biomass (000's tonnes) at maturity by strata. Totals do not account for the "possibly" herring classification Celtic Sea and VIIj herring survey 2006.

Strata	Immature	Mature	Spent	Total
1	-	1.5	-	**1.6**
2	-	-	-	**0**
3	-	-	-	**0**
4	-	-	-	**0**
5	-	-	-	**0**
6	-	-	-	**0**
7	-	-	-	**0**
8	-	-	-	**0**
9	0.2	3.4	-	**3.6**
10	0.1	3.2	-	**3.2**
11	0.3	1.9	-	**2.2**
12	0.1	0.9	-	**1**
14	0.4	17.1	-	**17.5**
15	0.1	6.8	-	**6.9**
16	-	-	-	**0**
17	-	1.2	-	**1.2**
23	-	-	-	**0**
24	-	-	-	**0**
25	-	-	-	**0**
Total	**1.3**	**36**	**0**	**37.3**
%	**3.4**	**96.6**	**0**	**100**

Table 9. Herring abundance (millions) at maturity by strata. Totals do not account for the possibly herring classification. Celtic Sea and VIIj herring survey 2006.

Strata	Immature	Mature	Spent	Total
1	0.3	10.6	-	**10.9**
2	-	-	-	**0.0**
3	-	-	-	**0.0**
4	-	-	-	**0.0**
5	-	-	-	**0.0**
6	-	-	-	**0.0**
7	-	-	-	**0.0**
8	-	-	-	**0.0**
9	2.3	29.3	-	**31.6**
10	0.7	24.5	-	**25.2**
11	3.0	15.8	-	**18.8**
12	0.8	8.1	-	**8.9**
14	4.4	140.3	-	**144.7**
15	1.4	55.3	-	**56.7**
16	-	-	-	**0.0**
17	0.2	8.4	-	**8.6**
23	-	-	-	**0.0**
24	-	-	-	**0.0**
25	-	-	-	**0.0**
Total	**13.1**	**292.3**	**0**	**305.42**
%	**4.3**	**95.7**	**0**	**100**

Table 10. Herring length at age (winter rings) as abundance (millions) and biomass (000's tonnes). Celtic Sea and VIIj herring survey 2006.

Length	Age										Abundance	Biomass	Mn wt
(cm)	0	1	2	3	4	5	6	7	8	9	(millions)	000's t	(g)
15.5	0.1	-	-	-	-	-	-	-	-	-	0.07	-	44.9
16	0.1	-	-	-	-	-	-	-	-	-	0.14	0.01	48.2
17	0.1	-	-	-	-	-	-	-	-	-	0.14	0.01	55.3
19.5	-	0.1	-	-	-	-	-	-	-	-	0.12	0.01	75.5
20	-	0.1	-	-	-	-	-	-	-	-	0.1	0.01	80
20.5	-	0.7	-	-	-	-	-	-	-	-	0.67	0.06	84.6
21	-	1.8	-	-	-	-	-	-	-	-	1.79	0.16	89.4
21.5	-	2.5	2.5	-	-	-	-	-	-	-	4.94	0.47	94.3
22	-	4	14	-	-	-	-	-	-	-	17.82	1.77	99.4
22.5	-	3.9	25	-	-	-	-	-	-	-	29.11	3.04	104.6
23	-	3.1	48	-	-	-	-	-	-	-	51.19	5.63	109.9
23.5	-	3.7	39	3.3	-	-	-	-	-	-	45.71	5.28	115.4
24	-	0.5	40	4.4	-	-	-	-	-	-	44.8	5.42	121.1
24.5	-	0.7	15	5.6	-	-	-	-	-	-	21.16	2.69	126.9
25	-	-	16	13	2.1	-	-	-	-	-	30.89	4.1	132.9
25.5	-	-	7.4	5.3	0.3	0.3	-	-	-	-	13.17	1.83	139
26	-	-	1.7	7.4	1.4	2	0.3	-	-	-	12.78	1.86	145.3
26.5	-	-	2.1	4.9	1.4	2.1	-	-	-	-	10.45	1.58	151.7
27	-	-	0.5	2.9	3.4	3.4	-	-	-	-	10.11	1.6	158.3
27.5	-	-	-	0.7	2.8	2.3	0.2	-	-	-	6.03	1	165.1
28	-	-	0.2	-	1.6	0.7	0.5	-	-	-	2.94	0.51	172
28.5	-	-	-	0.2	0.5	0.2	-	-	-	-	0.96	0.17	179.1
29	-	-	-	0.1	0.1	0.1	-	-	-	-	0.28	0.05	186.3
29.5	-	-	-	-	-	-	-	0	-	-	0.04	0.01	193.7
SSN	**-**	**16**	**204**	**48**	**14**	**11**	**1**	**0**	**-**	**-**	**292.27**	**-**	-
SSB	**-**	**1.7**	**24**	**6.5**	**2.1**	**1.7**	**0.2**	**0**	**-**	**-**	**-**	**35.974**	-
Mn wt (g)	**50**	**104**	**116**	**137**	**156**	**157**	**163**	**194**	**-**	**-**	**-**	**-**	-
Mn L (cm)	**17**	**23**	**24**	**26**	**27**	**27**	**28**	**30**	**-**	**-**	**-**	**-**	-

Table 11. Herring biomass and abundance by survey strata. Celtic Sea and VIIj Herring acoustic survey, October 2006.

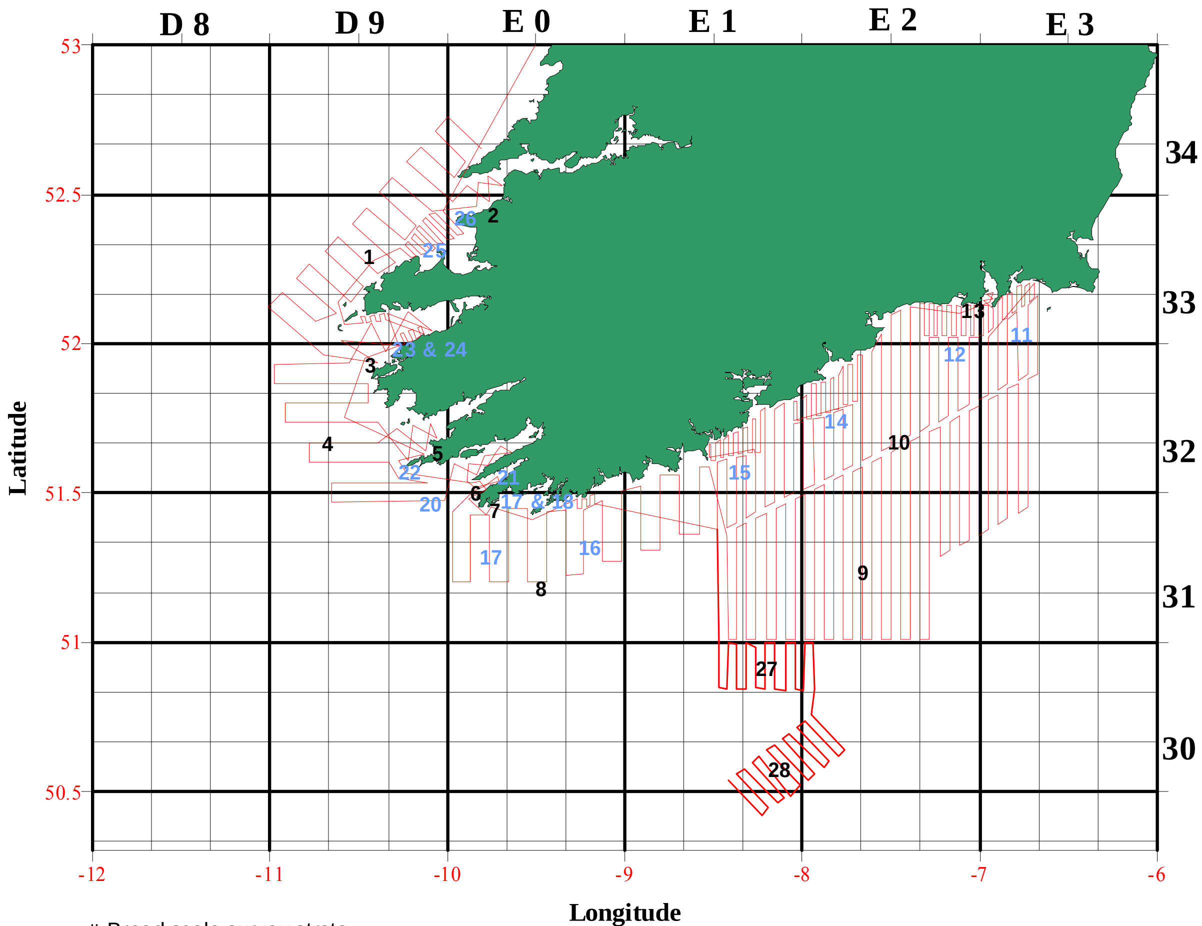
Category Stratum	No. transects	No. schools	Def schools	Mix schools	Prob schools	% zeros	Def Biomass	Mix Biomass	Prob Biomass	TSB (000's t)	SSB (000's t)	Abundance millions
1	14	2	2	-	-	93	1.6	-	-	1.6	1.5	10.91
2	5	-	-	-	-	100	-	-	-	-	-	-
3	9	-	-	-	-	100	-	-	-	-	-	-
4	8	-	-	-	-	100	-	-	-	-	-	-
5	7	-	-	-	-	100	-	-	-	-	-	-
6	7	-	-	-	-	100	-	-	-	-	-	-
7	3	-	-	-	-	100	-	-	-	-	-	-
8	14	-	-	-	-	100	-	-	-	-	-	-
9	32	32	3	27	2	94	0.4	3.1	0.2	3.6	3.4	31.58
10	34	11	-	7	4	88	-	0.5	2.7	3.2	3.2	25.21
11	9	11	6	-	5	44	1.8	-	0.4	2.2	1.9	18.79
12	16	26	-	26	-	50	-	1	-	1	0.9	8.92
14	16	30	17	-	13	69	14.5	-	3.1	17.5	17.1	144.73
15	13	25	25	-	-	23	6.9	-	-	6.9	6.8	56.73
16	5	-	-	-	-	100	-	-	-	-	-	-
17	12	8	8	-	-	83	1.2	-	-	1.2	1.2	8.57
23	6	-	-	-	-	100	-	-	-	-	-	-
24	6	-	-	-	-	100	-	-	-	-	-	-
25	10	-	-	-	-	100	-	-	-	-	-	-
Total	**226**	**145**	**61**	**60**	**24**	**84**	**26.3**	**4.6**	**6.3**	**37.3**	**36**	**305.42**
Cv (%)										**34.5**	**34.6**	**35**

Table 12. Celtic Sea and VIIj Herring acoustic survey time series. Abundance (millions), TSB and SSB (000's tonnes). Age in winter rings.
*** The 1999/2000 July survey was not used in tuning.**

Season	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	1999	2000	2001	2002	2003	2004	2005	2006
Age	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000***	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**
0	205	214	142	259	41	5	3	-	-	13	-	23	19	-	25	26	13	-
1	132	63	427	217	38	280	134	-	21	398	23	18	30	41	73	13	54	21
2	249	195	117	438	127	551	757	-	157	208	97	143	160	176	323	29	125	211
3	109	95	88	59	160	138	250	-	150	48	85	36	176	142	253	32	26	48
4	153	54	50	63	11	94	51	-	201	8	16	19	40	27	61	16	50	14
5	32	85	22	26	11	8	42	-	109	1	21	7	44	6	16	3	20	11
6	15	22	24	16	7	9	1	-	32	1	8	3	23	8	5	1	5	1
7	6	5	10	25	2	8	14	-	30	-	2	2	17	3	2	-	1	-
8	3	6	2	2	3	9	1	-	4	-	1	-	11	-	-	-	-	-
9+	2	-	1	2	1	5	2	-	1	-	-	1	23	-	-	-	-	-
Abundance	904	739	882	1107	399	1107	1253		705	677	252	250	542	404	758	119	292	305
TSB	103	84	89	104	52	135	151		111	58	30	33	80	49	89	13	33	37
SSB	91	77	71	90	51	114	146		111	23	26	32	74	39	86	10	30	36

Table 13. Scad biomass and abundance by survey strata. Celtic Sea and VIIj Herring acoustic survey, October 2006.

Category Stratum	No. transects	No. schools	Def schools	Prob schools	Mix schools	Her mix schools	% zeros	Def Biomass	Prob Biomass	S Mix Biomass	H Mix Biomass	Biomass (000's t)	Abundance (millions)
1	14	12	12	-	-	-	93	2.2	-	-	-	2.2	12.00
2	5	-	-	-	-	-	100	-	-	-	-	-	0.00
3	9	-	-	-	-	-	100	-	-	-	-	-	0.00
4	8	-	-	-	-	-	100	-	-	-	-	-	0.00
5	7	7	-	7	-	-	71	-	1.1	-	-	1.1	5.92
6	7	-	-	-	-	-	100	-	-	-	-	-	0.00
7	3	-	-	-	-	-	100	-	-	-	-	-	0.00
8	14	-	-	-	-	-	100	-	-	-	-	-	0.00
9	32	27	-	-	-	27	94	-	-	-	-	-	0.16
10	34	7	-	-	-	7	94	-	-	-	-	-	0.00
11	9	-	-	-	-	-	100	-	-	-	-	-	0.00
12	16	26	-	-	-	26	50	-	-	-	3	3	17.05
14	16	-	-	-	-	-	100	-	-	-	-	-	0.00
15	13	-	-	-	-	-	100	-	-	-	-	-	0.00
16	5	-	-	-	-	-	100	-	-	-	-	-	0.00
17	12	-	-	-	-	-	100	-	-	-	-	-	0.00
23	6	-	-	-	-	-	100	-	-	-	-	-	0.00
24	6	-	-	-	-	-	100	-	-	-	-	-	0.00
25	10	-	-	-	-	-	100	-	-	-	-	-	0.00
Total	**226**	**79**	**12**	**7**	**0**	**60**	**93**	**2.2**	**1.1**	**0**	**3**	**6.4**	**35.14**
Cv (%)	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**44.5**	**43.9**



Broad scale survey strata

Spawning box strata

Figure 1. Cruise track (red line) and numbered survey strata as adopted for the Celtic Sea and Division VIIj herring acoustic survey October, 2006.

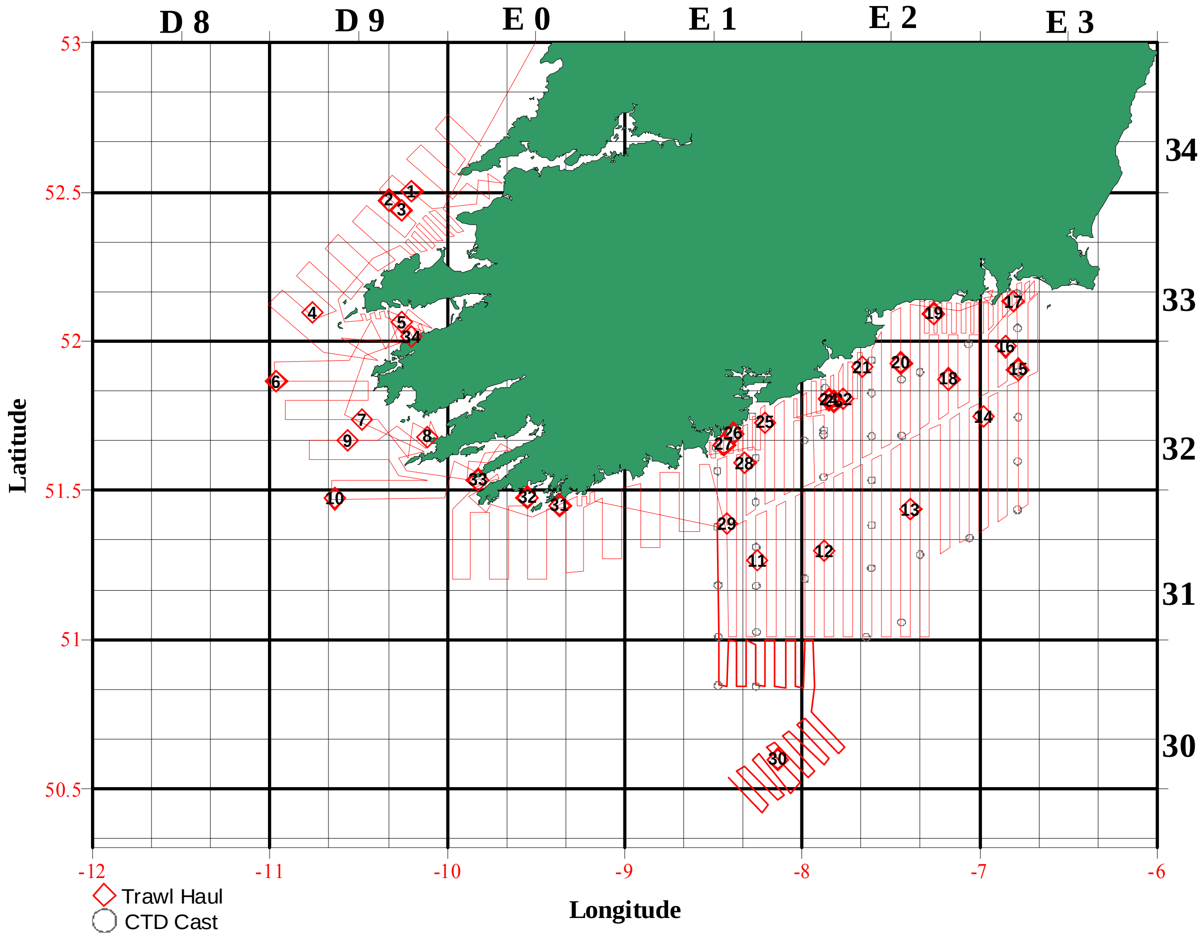


Figure 2. Cruise track haul positions and hydrographic stations. Celtic Sea and Division VIIj herring acoustic survey October 2006.

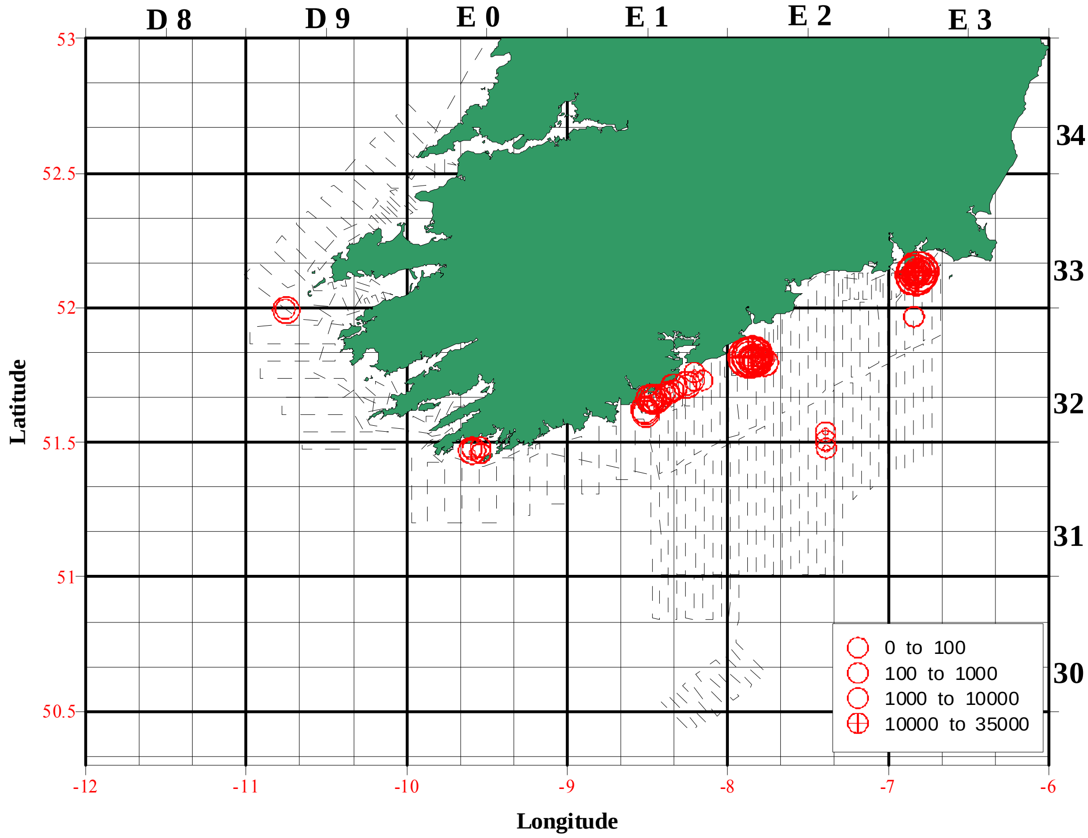


Figure 3. Herring NASC plot showing the distribution of "definitely" and "probably" categories. Celtic Sea and Division VIIj herring acoustic survey, October, 2006.

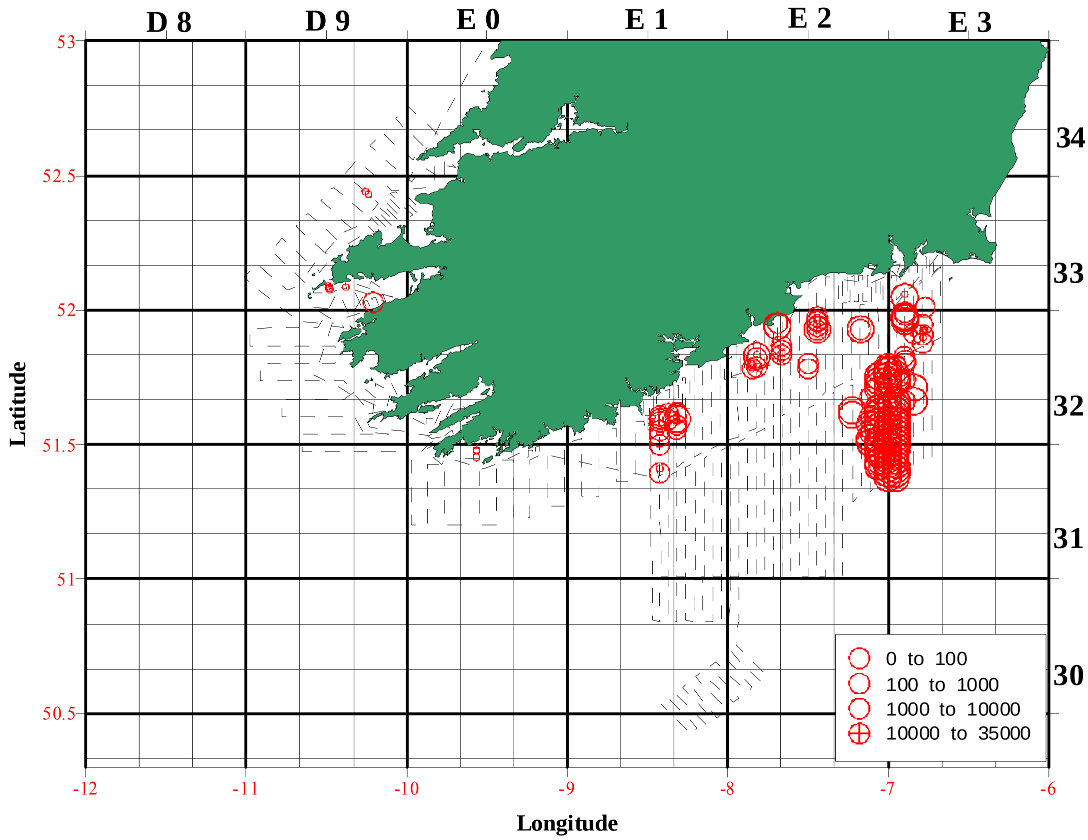


Figure 4. Mackerel NASC plot showing the distribution of "definitely" and "probably" categories. Celtic Sea and Division VIIj herring acoustic survey, October, 2006.

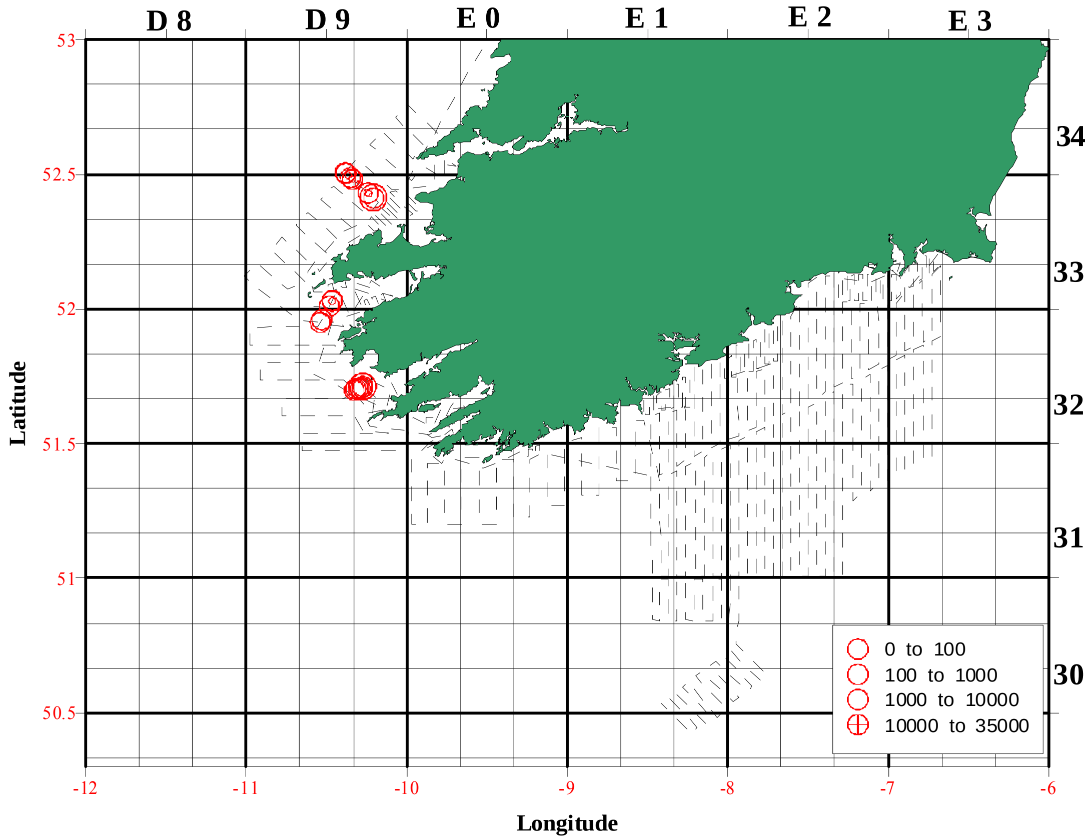
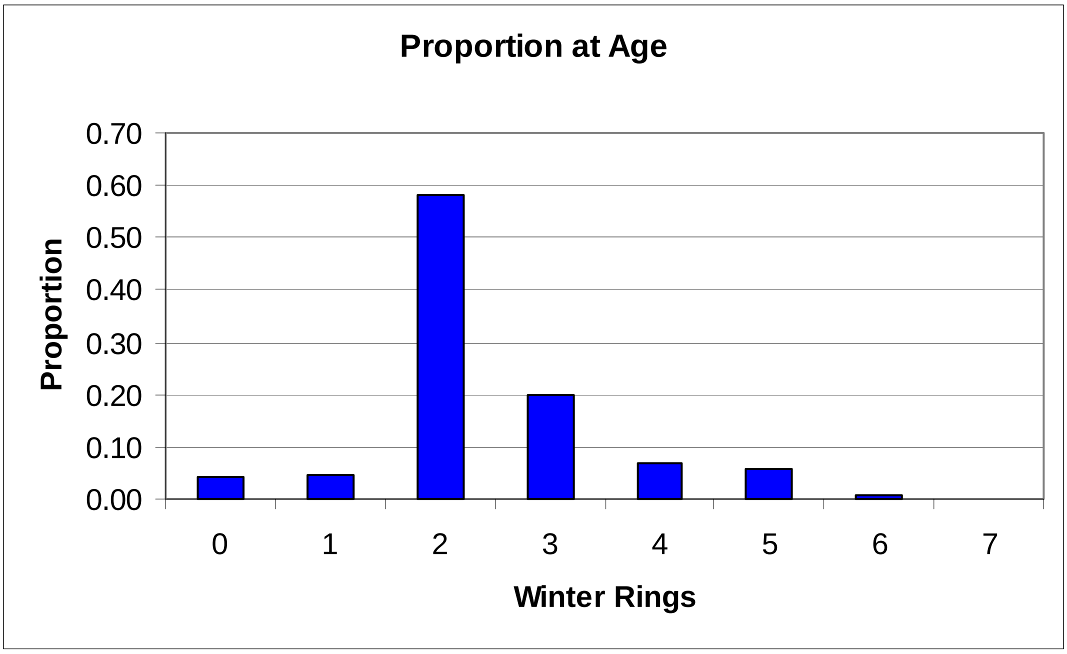


Figure 5. Scad NASC plot showing the distribution of "definitely" and "probably" categories. Celtic Sea and Division VIIj herring acoustic survey, October, 2006.



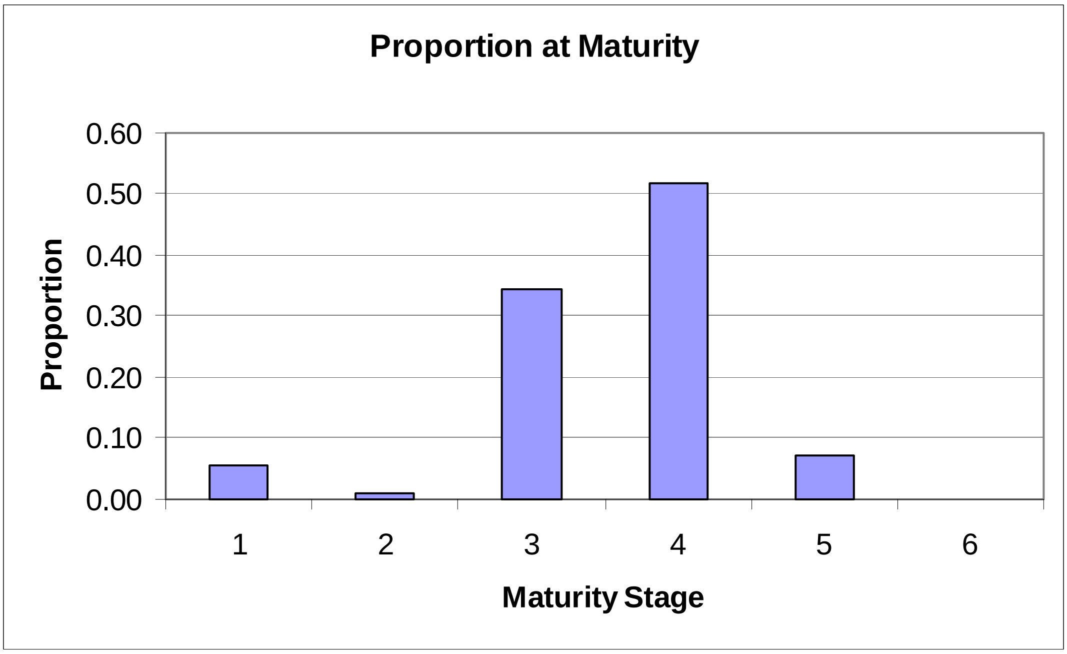
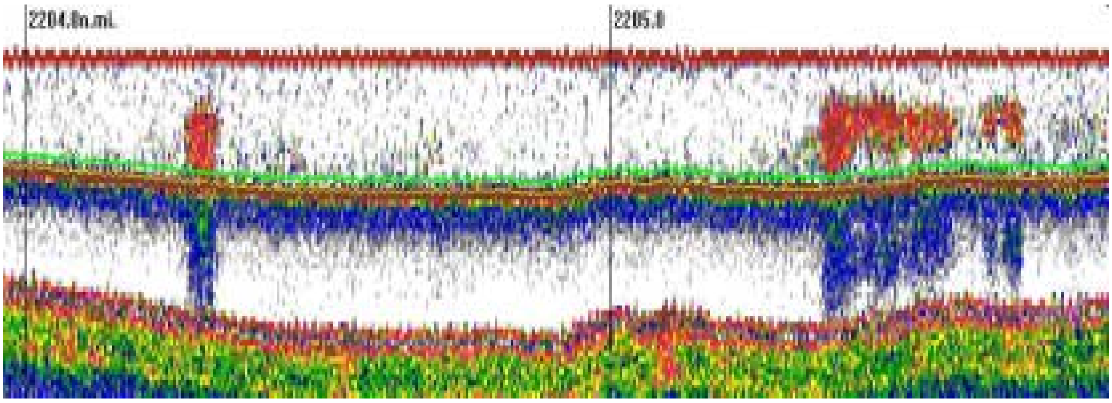
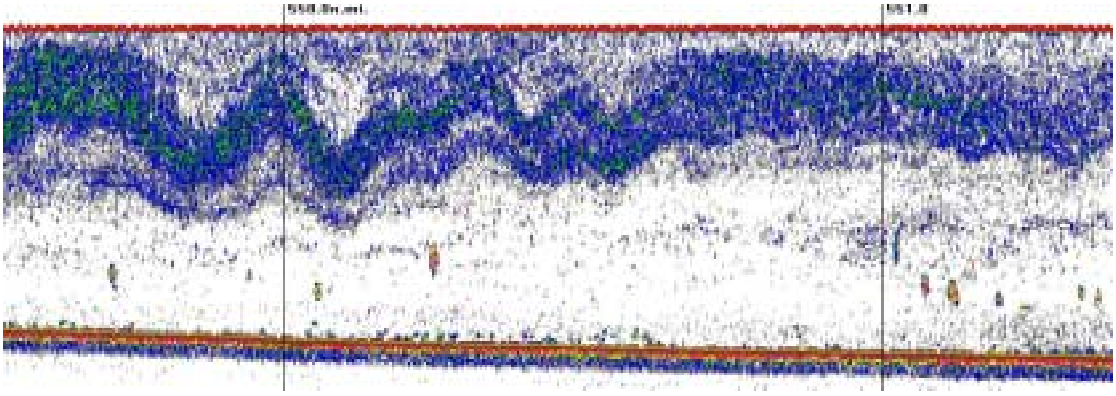


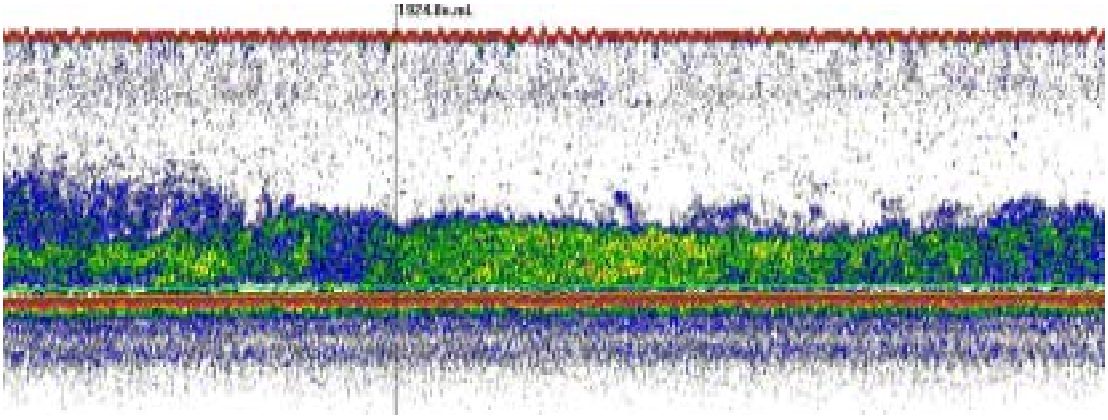
Figure 6. Breakdown of herring ages (above) and maturity (below) from combined survey trawl stations. Celtic Sea and Division VIIj herring acoustic survey, October, 2006.



a). ***Herring*** mark up to 11m tall in 40m of water (Haul 17). Located in Baginbun spawning box.

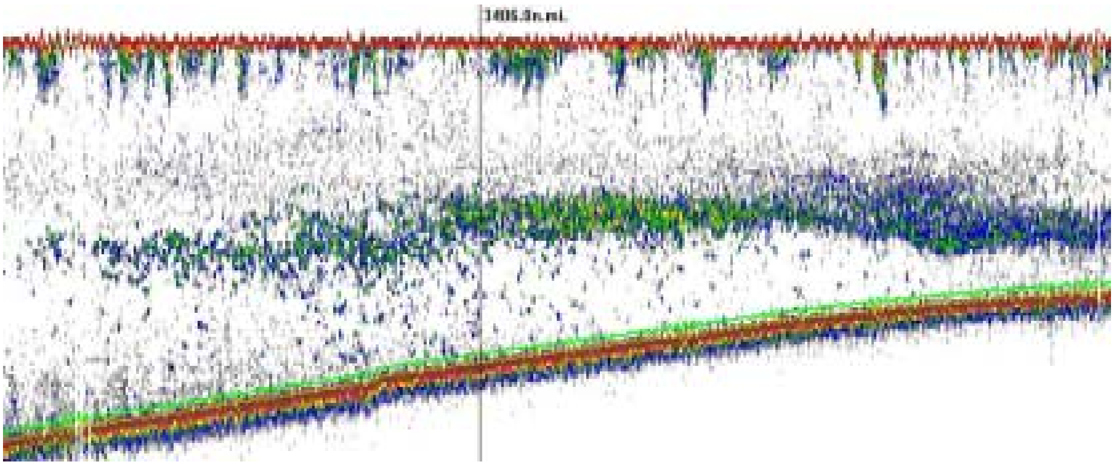


b). Midwater ***Borefish*** marks (small red vertical columns) up to 4m tall in 85m of water (Haul 09). Located in strata 4.

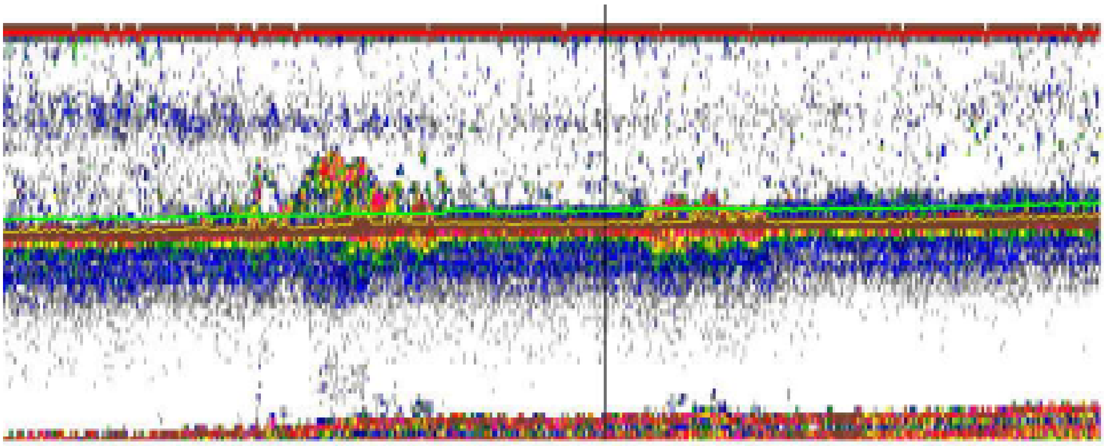


c). Bottom 0-1 group ***Mackerel*** mark up to 16m tall and just off the bottom in 66m of water (Haul 14). Located in strata 9.

Figure 7. Echograms (a-e) of main pelagic species encountered. Celtic Sea and Division VIIj herring acoustic survey, October, 2006.



d). Midwater ***Grey gurnard*** mark (green,yellow,red mark) up to 9m tall 9-25m off the bottom in 72m. Located on the Labadie Bank in strata 28.



e). ***Scad mark*** (large red bottom marks) up to 9m tall located on top of hard bottom feature in 41m of water (Haul 17) in Tramore spawning box, strata 12.

Figure 7. continued.

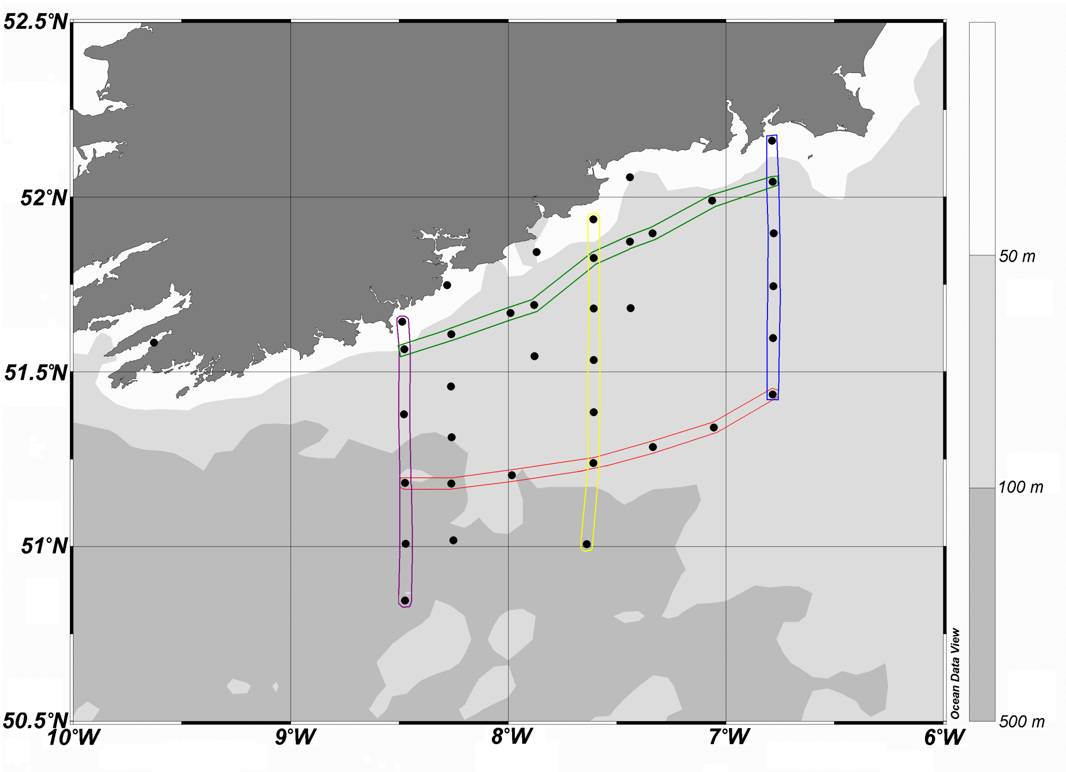
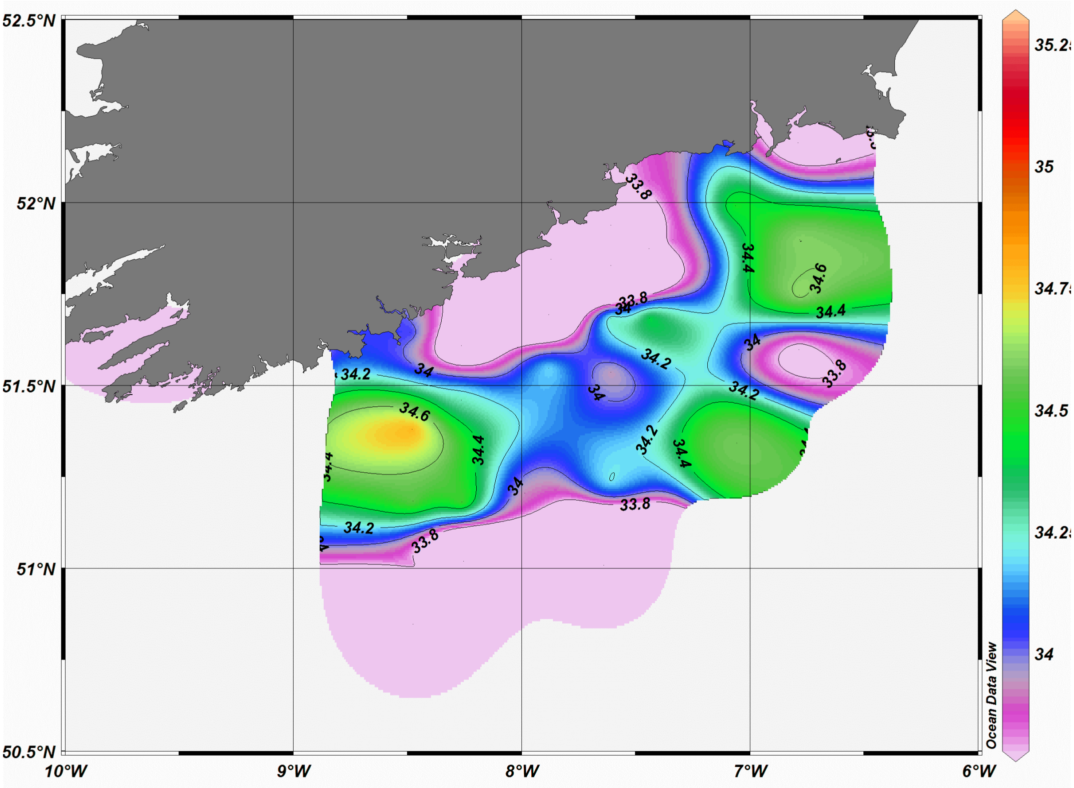
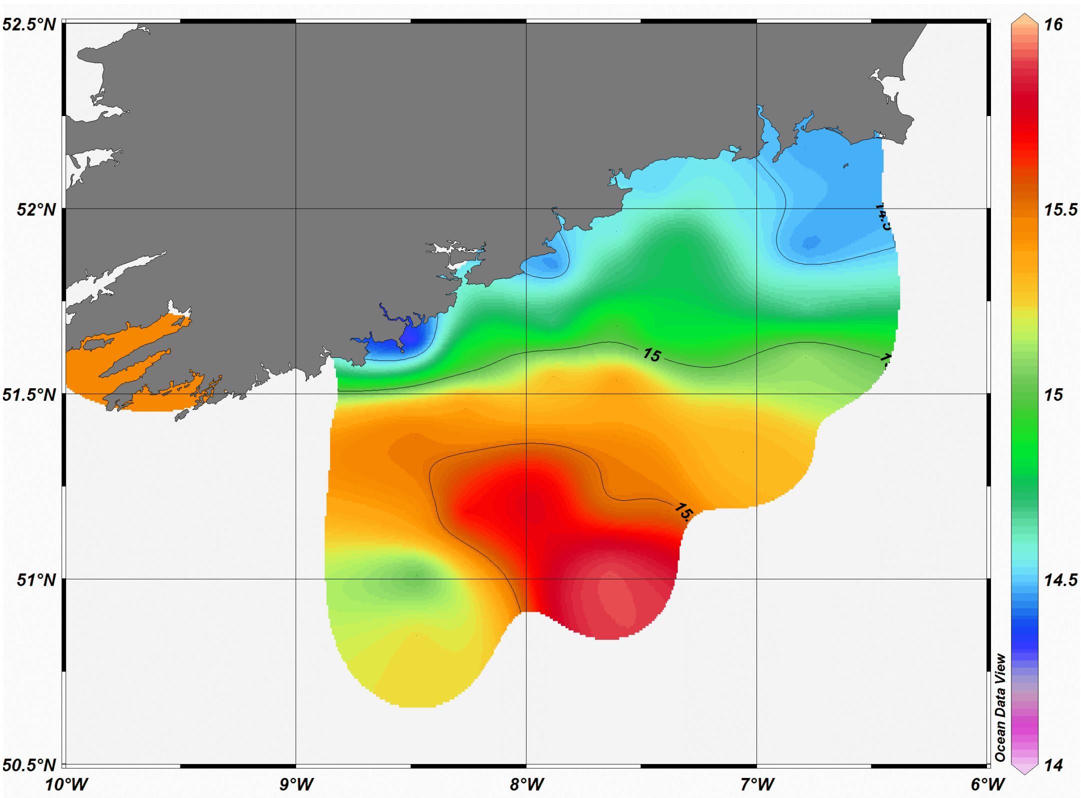


Figure 8. Hydrographic stations completed during the Celtic Sea and Division VIIj herring acoustic survey, with the following primary transects marked: North/South transects at Kinsale (purple), Ram Head (yellow) and Baginbun (blue), long-shore sections Inner (green) and Outer (red). Secondary north south transect stations (black dots) from west to east; Daunt; Ballycotton and Tramore.

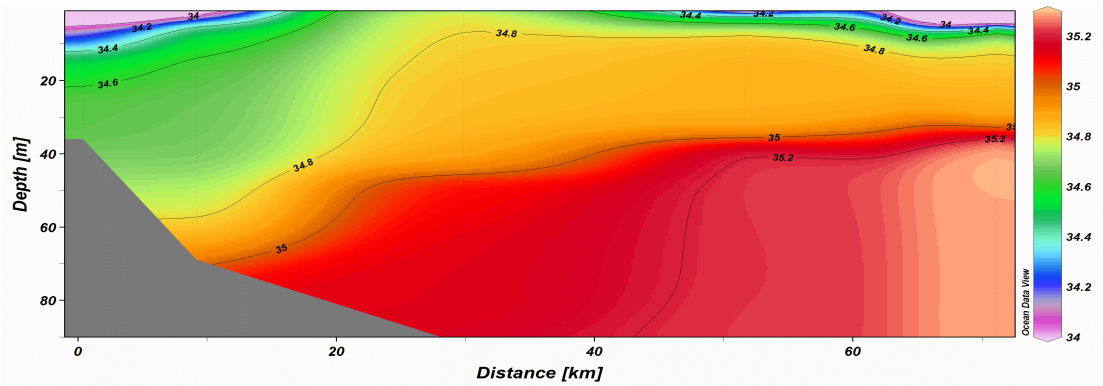


Salinity distribution at 3 m depth. Contour interval 0.2 PSU.

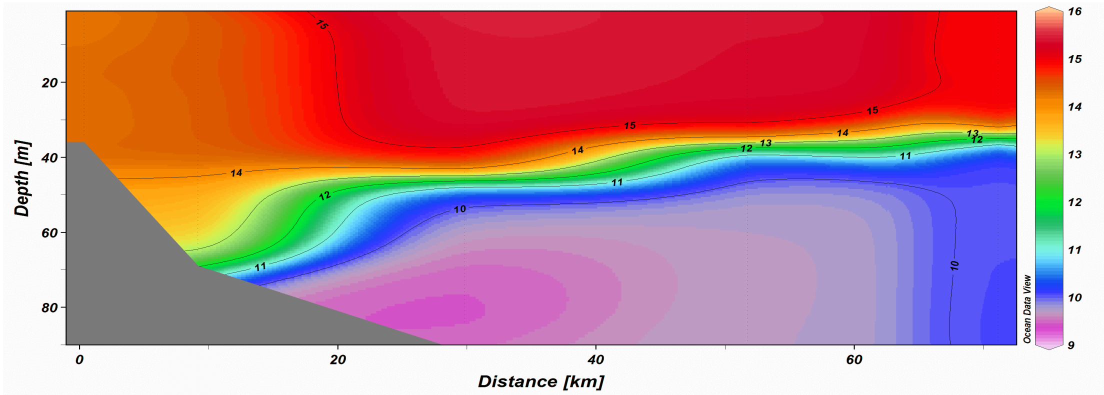


Temperature distribution at 3 depth. Contour interval 1°C.

Figure 9. Horizontal salinity (above) and temperature (below) distribution taken at 3m subsurface from combined CTD cast data. Celtic Sea and Division VIIj herring acoustic survey, October 2006.

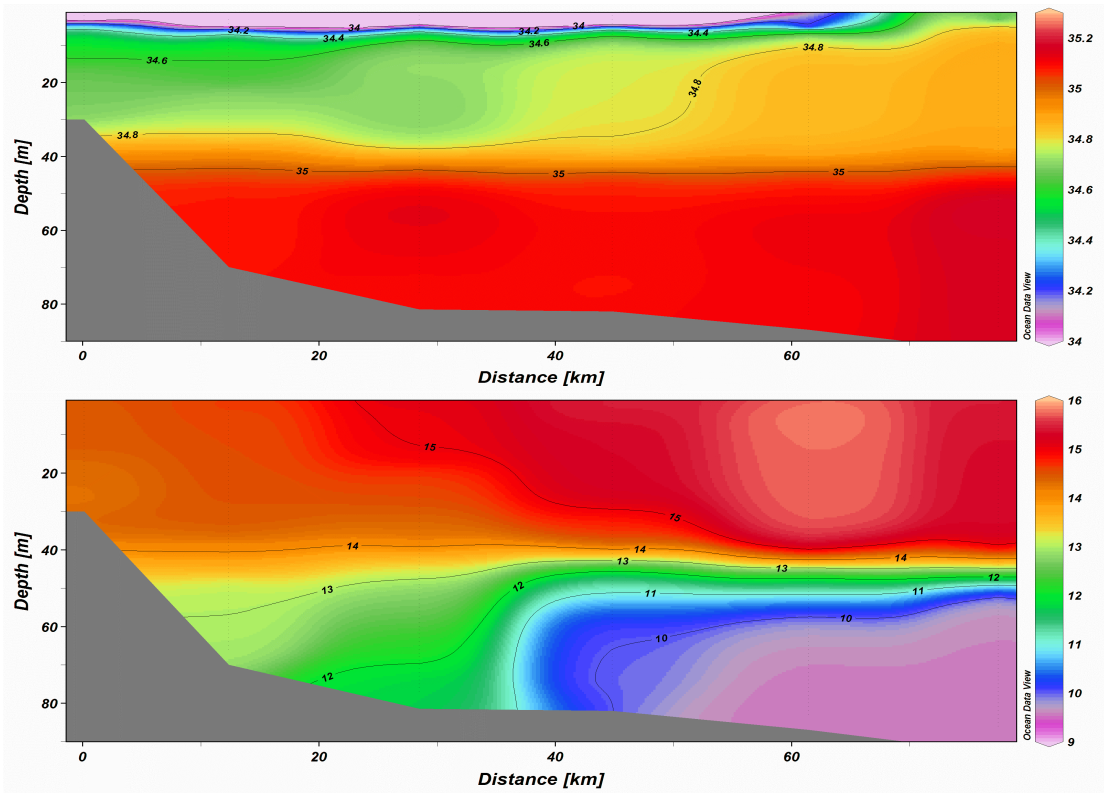


Contour interval 0.2 PSU, as on all following salinity plots.

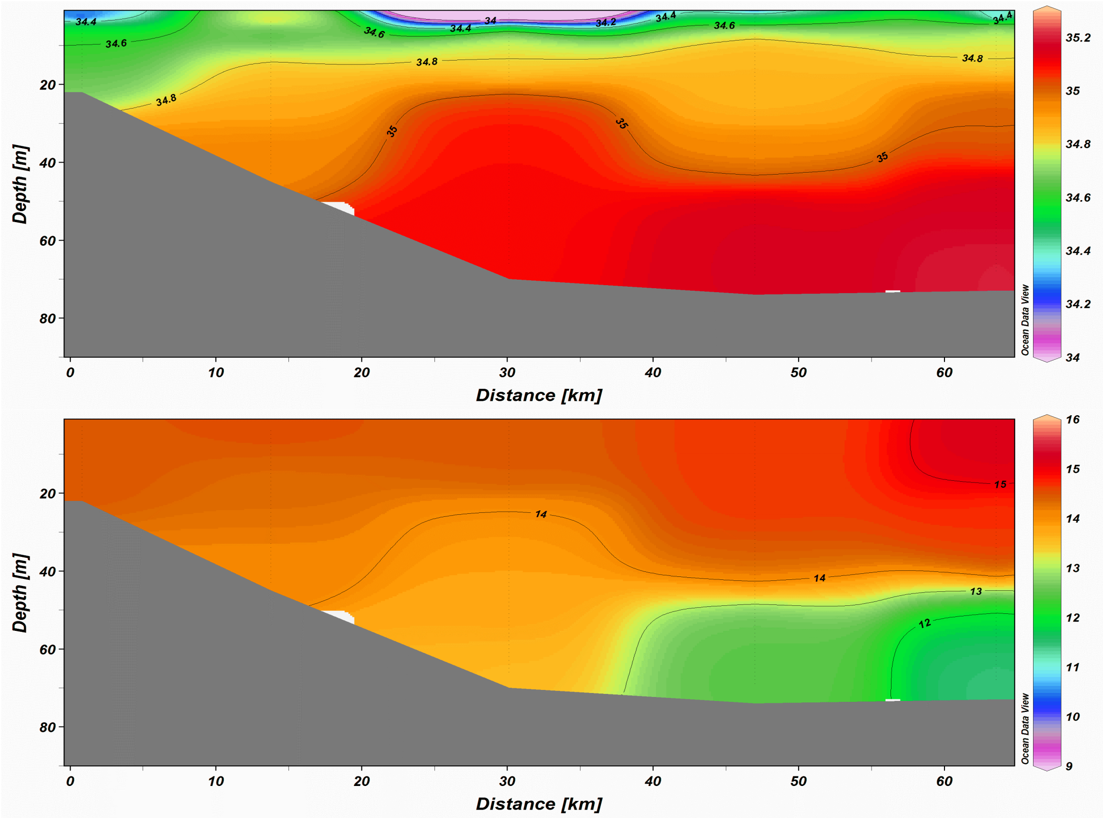


Contour interval 1°C, as on all following temperature plots.

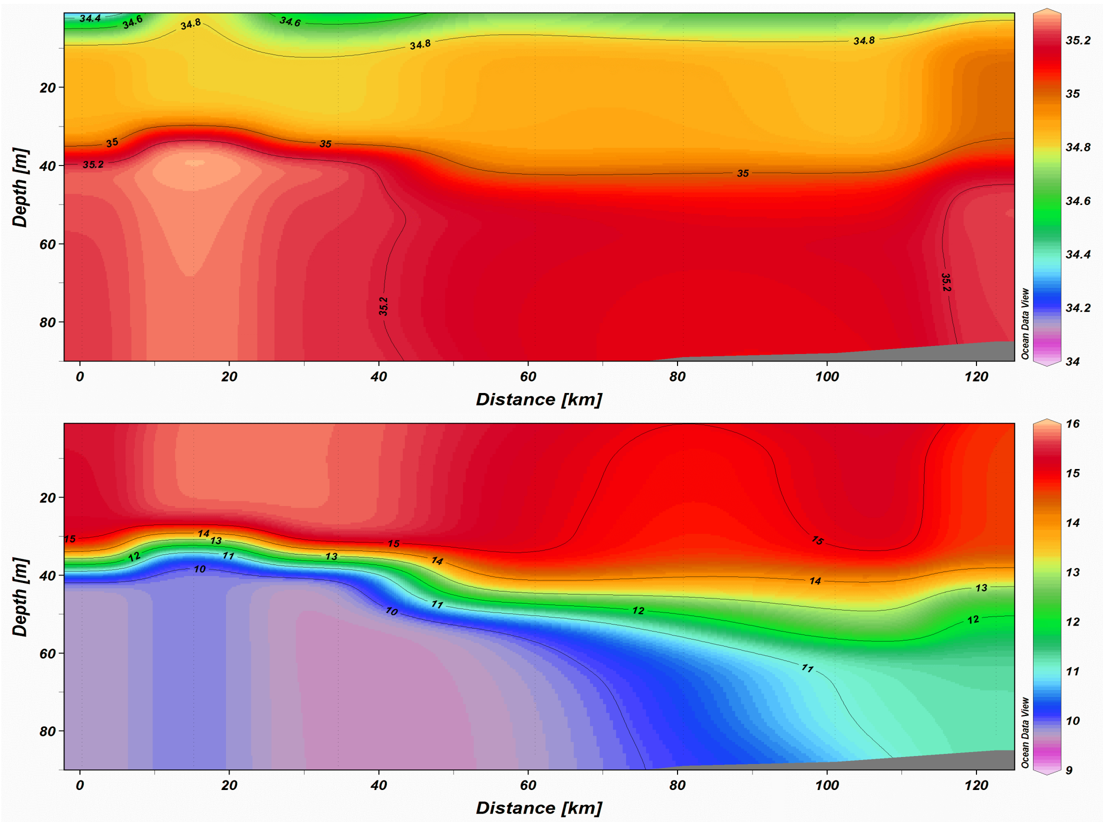
Figures 10. Vertical distribution of salinity (above) and temperature (below) of the Kinsale transect. Celtic Sea and Division VIIj herring acoustic survey, October 2006.



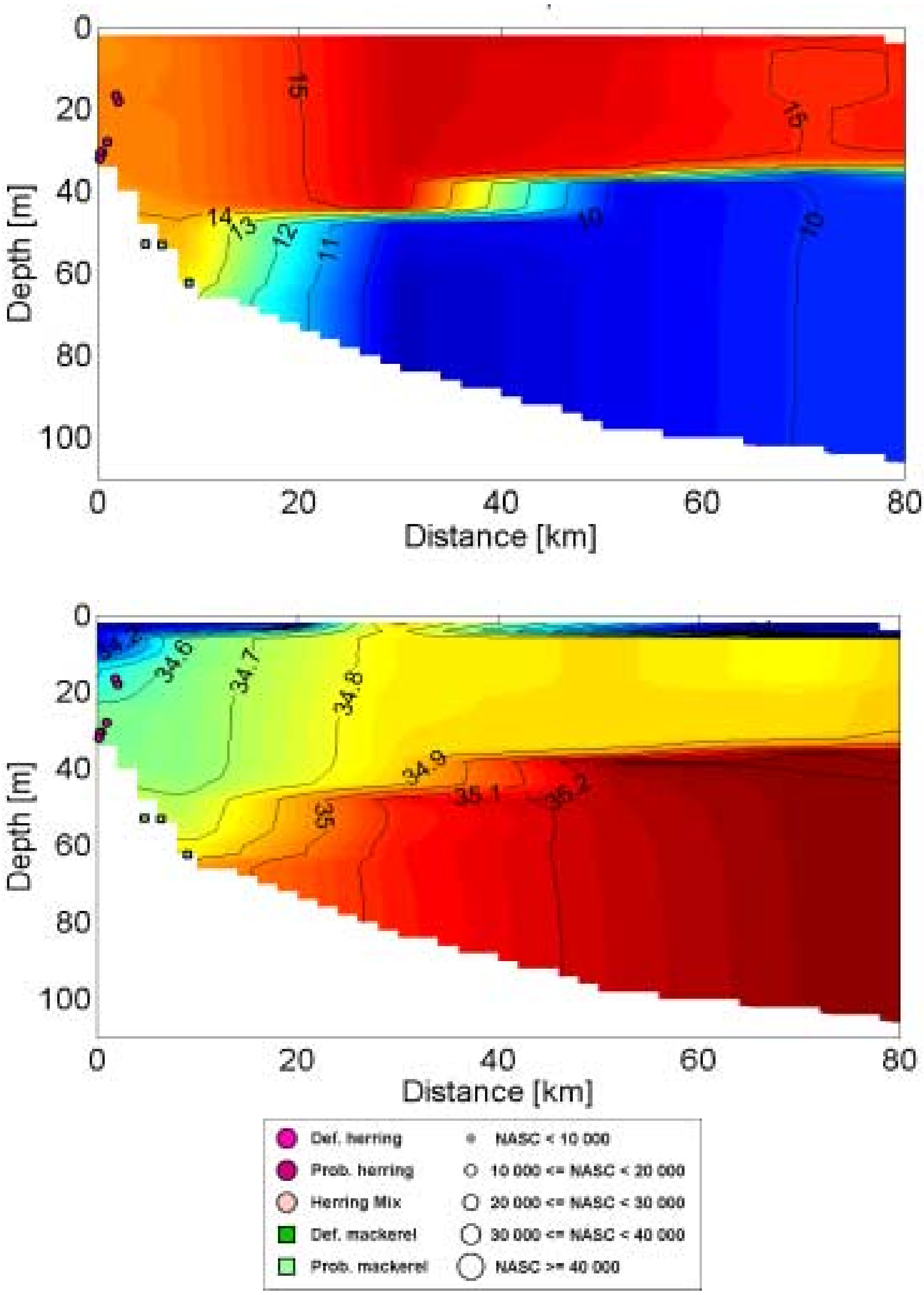
Figures 11. Vertical distribution of salinity (above) and temperature (below) of the Ram Head transect. Celtic Sea and Division VIIj herring acoustic survey, October 2006.



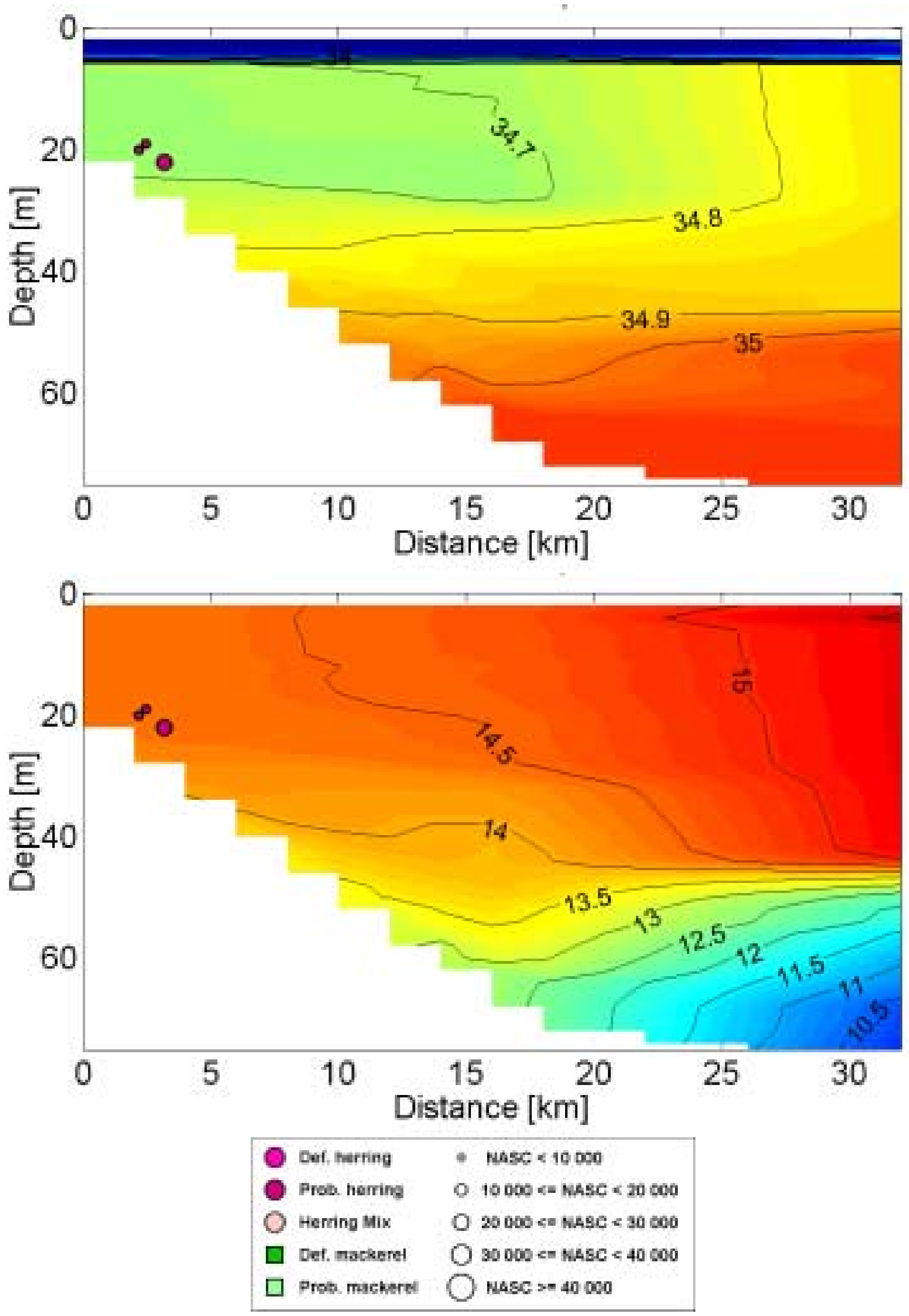
Figures 12. Vertical distribution of salinity (above) and temperature (below) of the Baginbun transect. Celtic Sea and Division VIIj herring acoustic survey, October 2006.



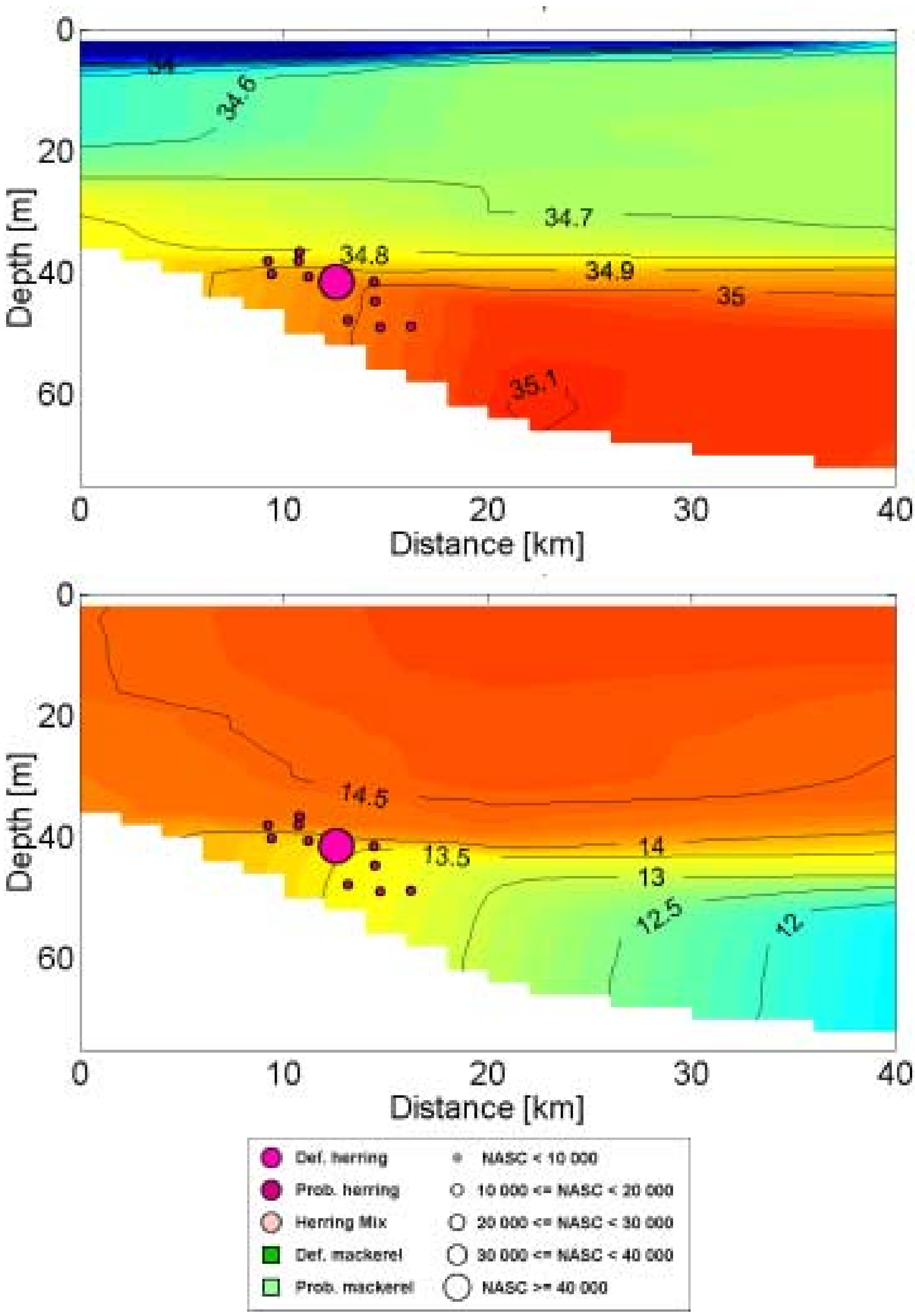
Figures 13. Vertical distribution of salinity (above) and temperature (below) of the Longshore transect. Celtic Sea and Division VIIj herring acoustic survey, October 2006.



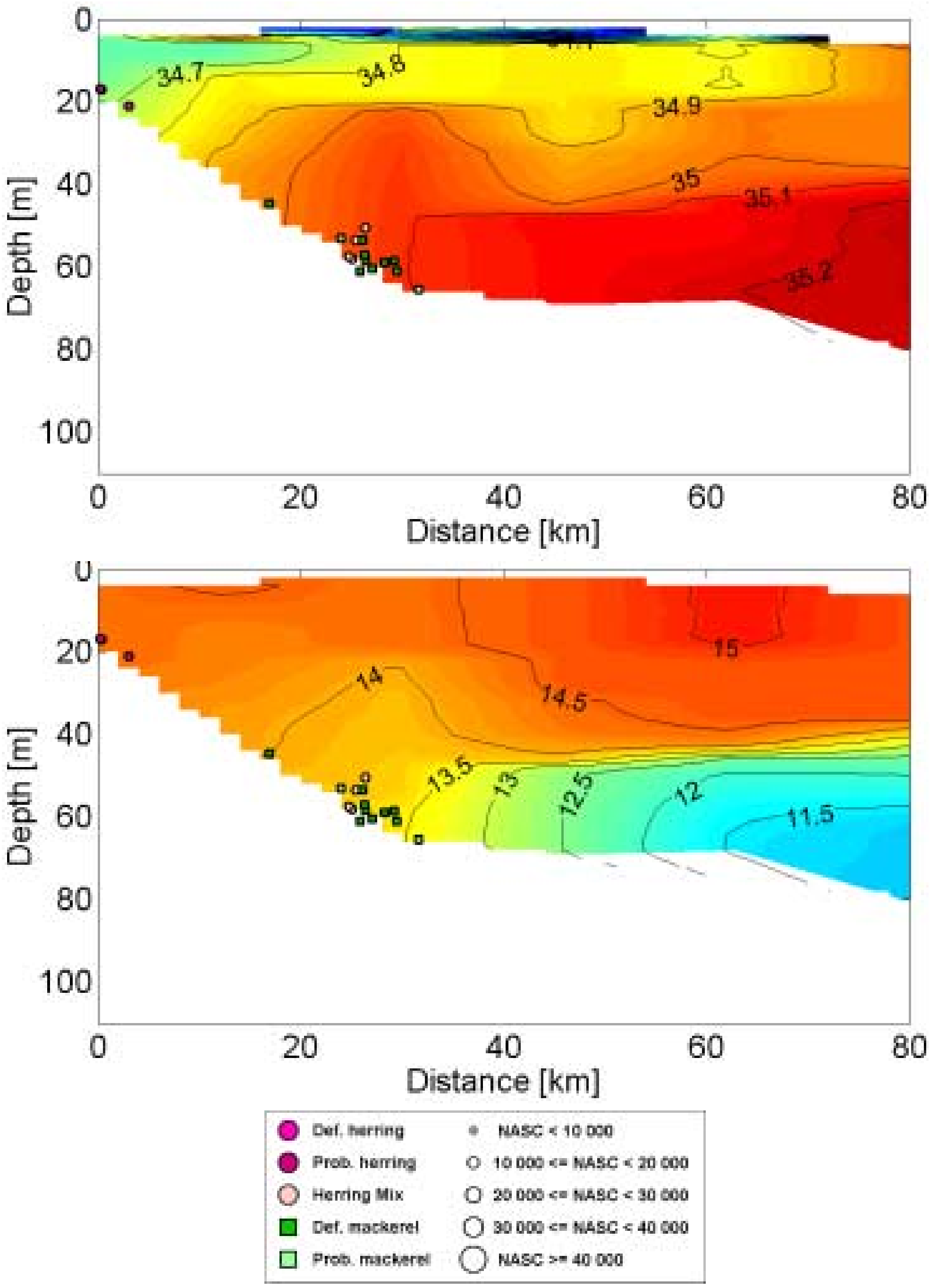
Figures 14. Vertical distribution of pelagic fish NASC (Nautical area scattering coefficient) in relation to salinity (above) and temperature (below) for the Kinsale transect. Celtic Sea and Division VIIj herring acoustic survey, October 2006.



Figures 15. Vertical distribution of pelagic fish NASC (Nautical area scattering coefficient) in relation to salinity (above) and temperature (below) for the Ram Head transect. Celtic Sea and Division VIIj herring acoustic survey, October 2006.



Figures 16. Vertical distribution of pelagic fish NASC (Nautical area scattering coefficient) in relation to salinity (above) and temperature (below) for the Tramore transect. Celtic Sea and Division VIIj herring acoustic survey, October 2006.



Figures 17. Vertical distribution of pelagic fish NASC (Nautical area scattering coefficient) in relation to salinity (above) and temperature (below) for the Baginbun transect. Celtic Sea and Division VIIj herring acoustic survey, October 2006.

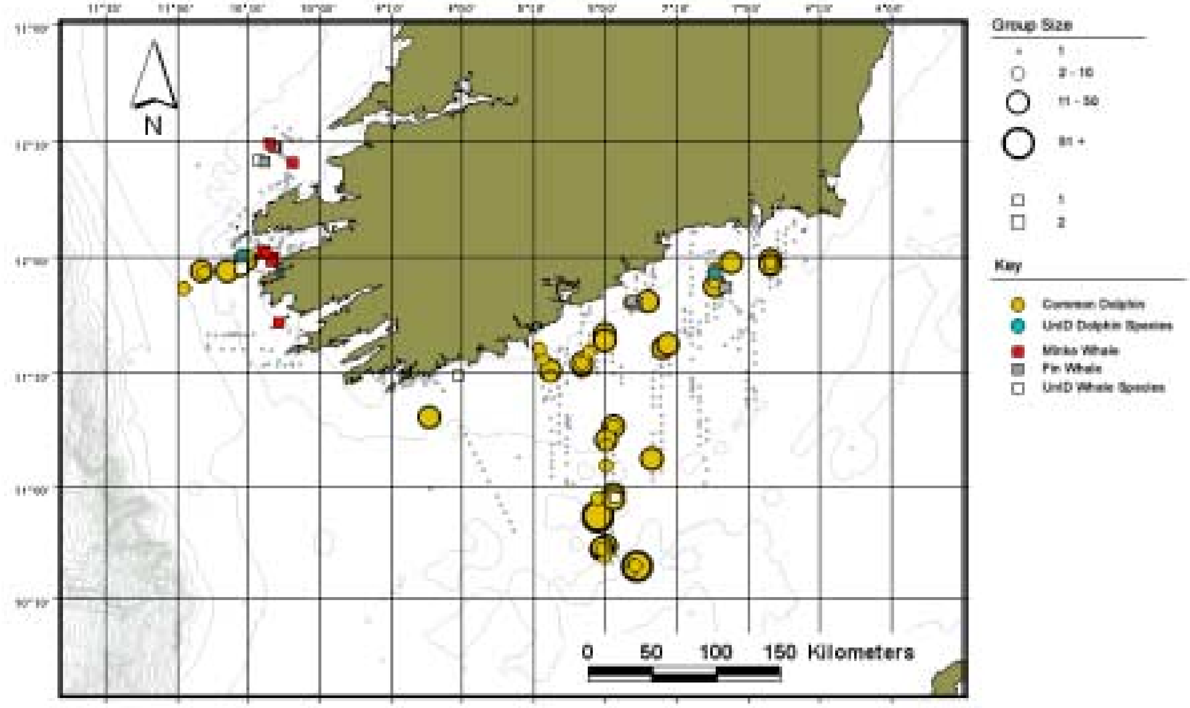


Figure 18. Distribution and size of cetacean sightings. Celtic Sea and Division VIIj herring acoustic survey, October 2006.

HERRING MIDWATER TRAWL

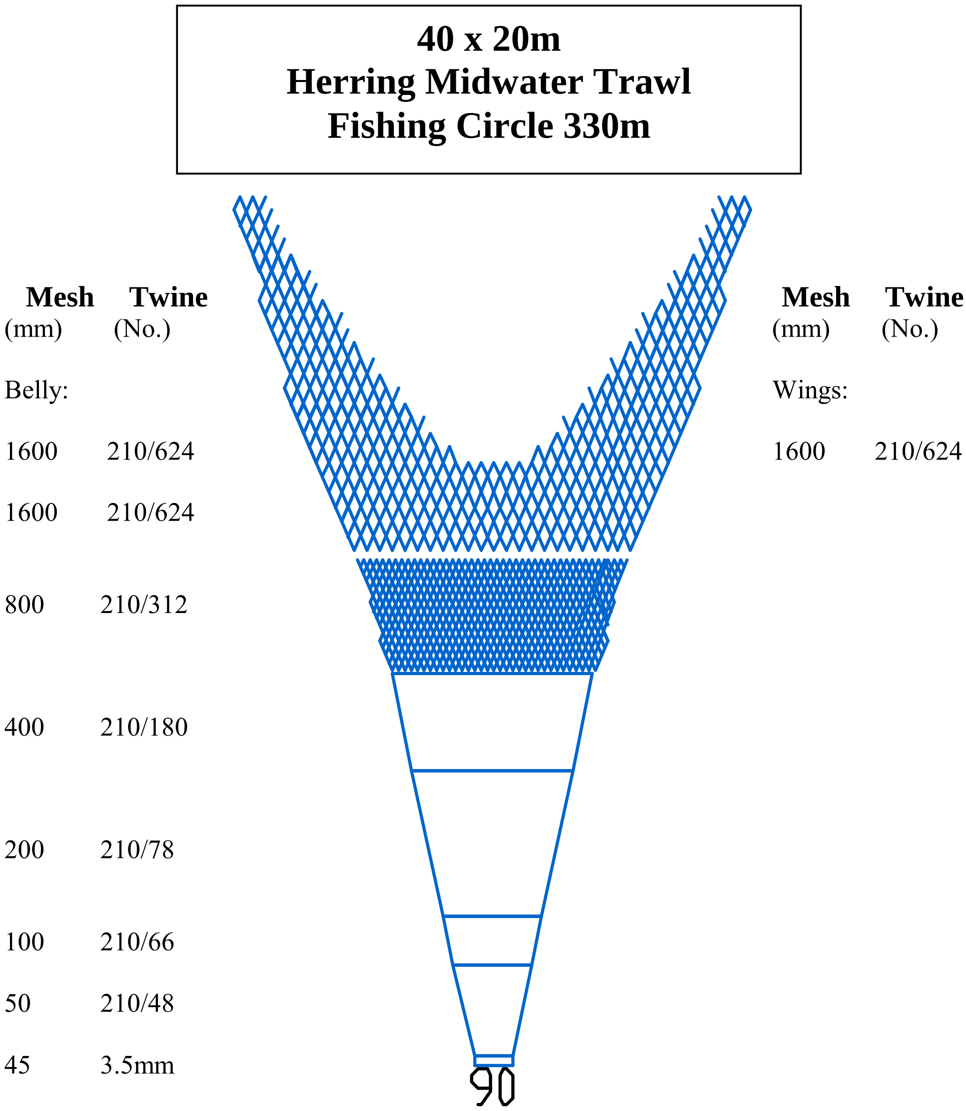


Figure 19. Single herring midwater trawl net plan and layout. Celtic Sea and Division VIIj herring acoustic survey, October, 2006. **Note:** All mesh sizes given in half meshes, schematic does not show 32m brailer.